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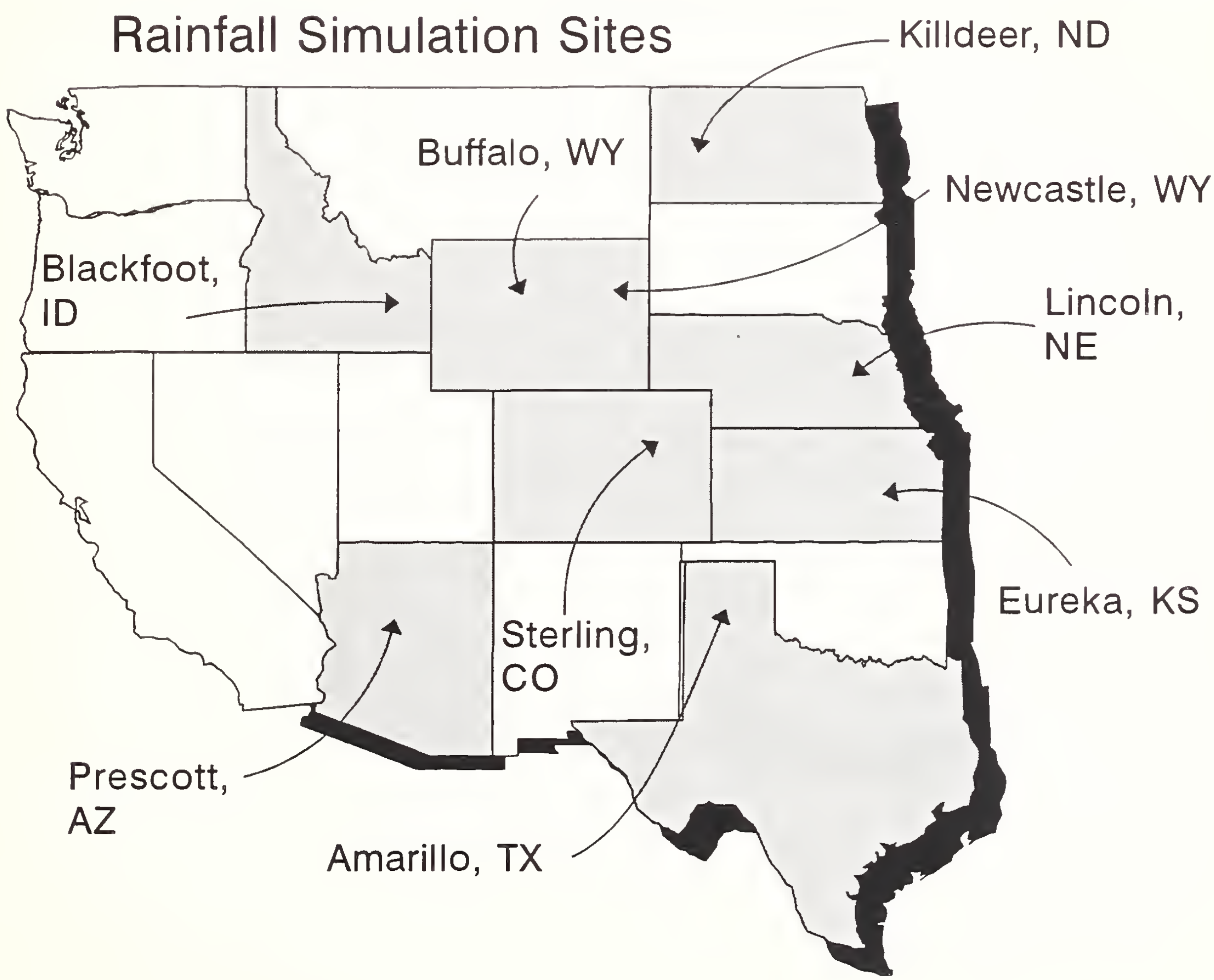
# Annual Progress Report
# Interagency Rangeland Water Erosion Project

National Range Study Team (NRST)

Interagency Rangeland Water Erosion Team (IRWET)



Special appreciation to ... an, D. Fox, K. Hood, F. Pierson, K. S

We wish to thank the f ... and IRWET:

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D. Woodruff, SCS CO-OP students, and ARS student interns

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# Interagency Rangeland Water Erosion Project
# FY-1992 Annual Progress Report

## EXECUTIVE SUMMARY

## Introduction

The increasing importance of water has produced new demands from rangelands and the concept of multiple use. In the Southwestern and Western United States, rangeland watersheds are important sources of surface water and ground water. The primary source of rangeland and surface water pollution is sediment produced from natural processes and management activities. Since rangelands comprise vast watershed areas in the United States (401.6 million acres of non-federal lands, about 28.5% of the total), it is of prime importance that policies and activities are implemented to update United States Department of Agriculture-Soil Conservation Service (USDA-SCS) technology for hydrology and erosion prediction.

## Traditional and State of the Art Perspectives

Society requires that the SCS maintain technical credibility by using "state of the art" methods to predict erosion rates and water yields on rangelands. The SCS is currently using the Hydrologic Curve Number method and the Universal Soil Loss Equation (USLE) for runoff and erosion predictions. The Hydrologic Curve Number method came into use in the mid-1950's; the USLE was developed from cropland research and was implemented in the mid 1960's. Both the Hydrologic Curve Number method and the USLE have limited applicability to rangelands, pasturelands, and forestlands.

Hydrology and erosion processes on rangelands are influenced by complex interactions of soil and vegetation factors. Rangelands are not homogeneous, even within seemingly continuous, unbroken expanses of grass. The kind of vegetation as well as the quantity of vegetation influences many hydrologic processes including: interception, infiltration, percolation, surface runoff, soil erosion, deposition of sediment, soil water storage, evaporation, and transpiration. Also, the spatial distribution of vegetation and temporal cycles of plant growth strongly influence rangeland hydrology and erosion.

In 1987, the USDA-Agricultural Research Service, Soil Conservation Service, USDA- Forest Service, and USDI-Bureau of Land Management organized to develop a new generation water erosion prediction technology called the Water Erosion Prediction Project (WEPP). Because rangelands are unique and diverse, model components of WEPP have been specifically developed for rangelands. Rangeland field data were collected during the early phases of the WEPP project; however, it became apparent that additional data, model enhancement, and validation were needed if WEPP was to be applied over a wide spectrum of rangeland sites.

This document summarizes the SCS, National Range Study Team (NRST) and ARS/SCS Interagency Rangeland Water Erosion Team (IRWET) activities—all in the context of supporting the WEPP effort by enhancing and validating the rangeland components of the WEPP model.

## Project Structure and Objectives

The NRST and IRWET are composed of SCS and ARS personnel. These two teams work in concert, but have different roles with respect to the project.

- **The National Range Study Team** was organized in 1990 to collect and develop quantitative data sets on soils, vegetation, hydrology, and erosion in two to four rangeland plant communities on approximately 15 different soils in 12 Midwest and Western States. This information will be used for WEPP model enhancement and validation purposes by the Interagency Rangeland Water Erosion Team. The data will also provide SCS with a national archive data base that can be used in resource planning and in development of hydrologic guides in range site descriptions.

- **The Interagency Rangeland Water Erosion Team** was established in April of 1991 to enhance the rangeland components of the WEPP model through: (1) improving the plant and soil relationships within the model to address vegetation induced spatial variability; (2) validating and testing the model on rangelands; (3) supporting technology transfer between SCS and ARS by

developing WEPP parameter data sets for all rangeland sites sampled by the National Range Study Team; and (4) developing appropriate technical materials for SCS and publishing results in appropriate scientific journals.

### Products

Several products will be produced by the IRWET effort: (1) quantitative data sets on hydrology, erosion, and vegetation to be archived for model enhancement, validation, and future use by SCS; (2) enhanced and validated hydrology, erosion, and vegetation components of the WEPP model that have been validated for selected rangeland sites; (3) enhanced parameterization techniques for the rangeland components of the WEPP model; (4) refereed journal articles, workshops and symposia, and technical reports; and (5) two highly qualified SCS personnel for implementing WEPP technology on rangelands.

### Accomplishments

Since the establishment of NRST in 1990 and IRWET in 1991 the following achievements have been made:

National Range Study Team

- Collected field data during 1990, 1991 and 1992 field seasons from 22 sites representing a gradient of climate, soil, vegetation, and management in eight states (Nebraska, Texas, Wyoming, Kansas, Colorado, North Dakota, Idaho and Arizona).
- Delivered to IRWET the hydrology, vegetation and soil data for Nebraska, Texas, Wyoming, Kansas and Colorado.
- Currently processing and reducing the 1992 data sets from North Dakota, Wyoming, Idaho and Arizona and finalizing the selection of study sites for the 1993 field season in California, Nevada, Utah and Colorado.
- Participated in the development of an implementation plan for the NRST and IRWET effort.
- Provided field training in range hydrology to SCS national staff, technical center, state, area, and field office personnel.
- Presented 3 seminars on NRST at Lincoln, Nebraska, and at the Annual Society for Range Management meeting in Spokane, Washington.
- Hosted field demonstrations for Society for Range Management, Soil and Water Conservation Society (Wyoming Sections) and SCS, Midwest National Technical Center.
- Completed several public relations and technology transfer activities such newspaper, radio and television interviews.
- Published feature story on NRST in RANGELANDS magazine.

Interagency Rangeland Water Erosion Team

- Cooperative agreements between ARS and SCS to implement and staff IRWET were completed in April 1991.
- Completed implementation plan for enhancement and validation of the hydrologic, erosion, and vegetation components of WEPP for use on rangelands.
- Assisted NRST with field data collection efforts and refined field procedures in Wyoming, Kansas, Colorado, Idaho and Arizona.
- Developed a functional database management system to facilitate the organization, reduction, and analysis of the NRST data, Tucson ARS/SCS rangeland hydrology data (1987 and 1988) and other related data sets.
- Significant progress has been made on four research projects aimed at validating and enhancing the rangeland hydrology, erosion and vegetation components of the WEPP model.

- Four cooperative projects are underway with university researchers related to meeting IRWET objectives.

- Parameter data sets for validating the WEPP model on rangelands have been developed for all 1990 and 1991 NRST sites and all 1986-1988 SCS/ARS WEPP rangeland sites.

- IRWET has been involved in numerous activities aimed at transferring information and technology to SCS, BLM, university and international personnel.

- 32 journal articles, symposium proceedings, technical bulletins, and 9 presentations were authored or co-authored by IRWET members during 1991 and 1992.

- Sponsored and coordinated Soil Science Society of America and Society for Range Management symposia.

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# Interagency Rangeland Water Erosion Project: FY-92 Annual Progress Report

## USDA-Soil Conservation Service and Agricultural Research Service

This report provides an overview of the duties and accomplishments of the National Range Study Team (NRST) and the Interagency Rangeland Water Erosion Team (IRWET). The Interagency Rangeland Water Erosion Project is an interagency effort comprised of these two teams which are made up of USDA-SCS and -ARS personnel. The NRST and IRWET work in concert, but have different roles with respect to the project.

## INTRODUCTION

The increasing importance of water to society has added a new dimension to the value of rangelands and has reinforced and expanded the concept of multiple use. Society's demands for improved water quality and quantity information on non-federal rangelands is increasing rapidly. The Soil and Water Resources Conservation Act of 1977 identified reduction of erosion and improvement of water quality and quantity as our nations highest resource priorities. Since the need for clean water is critical and rangelands comprise vast watershed areas in the United States (401.6 million acres of non-federal, about 28.5% of the total), it is of prime importance that policies and activities are formulated and implemented to arrest rangeland resource degradation. With passage of the National Clean Water Act and implementation of the 1985 Food Security Act, increased attention has been placed on sustained water quality and quantity on rangeland watersheds.

On rangelands, the hydrologic condition of a site is the result of complex interactions of soil and vegetation factors. Rangelands are not homogeneous, even within seemingly continuous unbroken expanses of grass. Mosaic patterns and patchiness prevalent in most rangeland plant communities are spatially heterogeneous and temporally dynamic. The kind of vegetation as well as the quantity of vegetation influences the spatial and temporal variability of many hydrologic processes including: interception, infiltration, evaporation, transpiration, percolation, surface runoff, soil water storage, soil erosion, and deposition of sediment.

Research in rangeland hydrology has demonstrated a significant correlation between kinds of vegetation, plant cover, and surface soil properties to infiltration, runoff and erosion (Rauzi et al. 1968, Blackburn 1975, Hanson et al. 1978, Blackburn 1984, Gifford 1984, Swanson and Buckhouse 1984; Blackburn et al. 1986, Johnson and Gordon 1988, Thurow et al. 1988, Wilcox and Wood 1989, Spaeth 1990, Blackburn et al. 1990, Blackburn et al. 1992). This has significant range management implications, in that vegetation can be manipulated to increase water quantity and quality from rangeland watersheds (Heede 1979, Blackburn 1983, Hibbert 1983, Thurow et al. 1988, Griffin and McCarl 1989). Our understanding of these relationships needs to be enhanced, and data bases and quantitative methods need to be developed for improving rangeland watershed management.

Society requires that the USDA-SCS must maintain technical credibility and "state of the art" methods to predict erosion rates and water yields on rangelands. Throughout the United States, the SCS is currently using the Hydrologic Curve Number method (SCS-NEH-4, 1985), and the Universal Soil Loss Equation (USLE)(Wischmeirer and Smith 1965, 1978) for runoff and erosion predictions. The Hydrologic Curve Number came into use in the mid-1950's; the USLE was developed from cropland research and was implemented in the mid 1960's. Both the Hydrologic Curve Number method and the USLE have limitations when applied to rangelands, pasturelands, and forestlands. The USLE was developed from years of field research on cropland primarily in the Central and Eastern United States. Most of the database from which USLE was developed and the range management methods and techniques addressed by the USLE model are not directly applicable to rangeland conditions. In 1987, the USDA-Agricultural Research Service, USDA-Soil Conservation Service, USDA- Forest Service, and USDI-Bureau of Land Management organized to develop a new generation water erosion prediction technology called the Water Erosion Prediction Project (WEPP).

Since rangelands are unique and diverse, rangeland components of the Water Erosion Prediction Project (WEPP) were established. Limited field data on rangelands were collected during the summers of 1987 and 1988 and used to begin development of the rangeland components. However, it soon became apparent that additional data were needed for model enhancement, and validation if WEPP was to be applied over a wide spectrum of rangeland sites.

The charge of this ARS/SCS cooperative effort is to improve our understanding of and predictive capability for simulating the influence of vegetation on hydrologic characteristics over a wide range of soils, and climatic conditions. Enhanced rangeland

WEPP technology will offer credence for projections associated with conservation planning, national inventories, and various program implementation guidelines. The National Range Study Team (NRST) is responsible for collecting and reducing the field data, while the Interagency Rangeland Water Erosion Team (IRWET) integrates the data and information into the WEPP technology and into appropriate technical and scientific documents.

WEPP technology needs to be enhanced for use on rangelands with special emphasis on the following:

(1) model components and parameterization algorithms that are sensitive to temporal and spatial variability of vegetation and soils;

(2) the hydrologic influence of rangeland use and improvements such as fire, grazing, seeding and seed bed preparation, herbicides, and mechanical treatments such as chiseling, range pitting, and mechanical brush control;

(3) pastureland hydrology; pasturelands are distinguished from rangelands by the fact that periodic cultivation is used to maintain introduced (non-native) forage species, and agronomic inputs such as irrigation and fertilization may be applied on a regular basis;

(4) woodland hydrology; the term woodlands rather than forest is applied to the pinyon-juniper and oak woodland types since the trees are usually below sawtimber size. These vegetation types are unique in that small trees and large shrubs are usually clustered with interspaces occupied by smaller shrubs, grasses and forbs;

(5) alpine and tundra ecosystems; these rangeland types are indicative of low growing perennial, herbaceous, shrubby vascular plants, extensive mats of cryptogams (mosses, lichens etc.) and the absence of trees. The alpine tundra is a very important source of water in the western United States (Johnston and Brown 1979);

(6) validation of the rangeland components of the model; and

(7) decision/support system with user interface.

## OBJECTIVES

National Range Study Team:

The objectives of the NRST are:

(1) collect and develop quantitative data sets on plant communities, soils, runoff, and erosion;

(2) provide reduced data sets to IRWET for use in enhancement and validation of WEPP components; and

(3) develop an SCS national archive data base.

Interagency Rangeland Water Erosion Team:

IRWET will focus it's efforts on model enhancements and parameterization algorithms that are sensitive to spatial and temporal variability of vegetation and soils, and on validation of the rangeland components of the model. IRWET's objectives are:

(1) to develop a data management system to reduce and analyze the SCS-NRST data sets and other hydrology data sets;

(2) to improve the rangeland plant/soil relationships within the WEPP model to address vegetation induced spatial variability;

(3) to enhance and validate the hydrologic, erosion, and vegetation components of the WEPP model on rangelands;

(4) to improve parameter estimation procedures for rangeland components of the WEPP model;

(5) to support technology transfer between SCS and ARS by developing WEPP parameter data sets for all rangeland sites sampled by the NRST;

(6) to cooperate with the Agricultural Research Service, National Soil Erosion Laboratory in

West Lafayette, Indiana to insure that the IRWET objectives and activities are compatible with the current WEPP effort;

(7) to deliver enhanced and validated rangeland hydrologic, erosion, and plant growth components of the WEPP model to the WEPP Core Team; and

(8) to publish results in appropriate scientific journals and develop appropriate technical materials for SCS.

**PRODUCTS**

1. SCS archived data set on plant communities, soils, runoff, and erosion that will be used to develop relationships for plant communities and soils.

2. National data set on rangeland erosion, hydrology, soils, and vegetation for validation and enhancement of the rangeland components of the WEPP model.

3. Data for inclusion into SCS national range and soils databases.

4. Enhanced hydrology, erosion and vegetation components of the WEPP model that have been validated for selected rangeland sites.

5. Enhanced parameterization procedures for rangeland components of the WEPP model.

6. Rangeland parameter data sets for the WEPP model for use by SCS state, area and field office personnel.

7. Workshops, conferences and symposiums.

8. Refereed journal articles, workshops and symposium proceedings, technical notes, and bulletins.

9. Annual oral and written reports for SCS National Ecological Sciences Division and ARS National Program Staff.

10. Two highly qualified SCS personnel for implementing the rangeland version of WEPP within the SCS.

**ORGANIZATIONAL STRUCTURE OF NRST AND IRWET**

Figure 1 depicts the organizational network of interacting agencies and subgroups within agencies which are involved in this effort. Details of the organizational structure of NRST and IRWET are given below.

<u>National Range Study Team</u>

1. Harlan DeGarmo, SCS, Supervisory Range Conservationist: Provides overall administrative leadership and supervision for the NRST. Coordinates the NRST's study proposal and collection of field data with the SCS National office and SCS Range Hydrologist working with ARS.

2. Mitch Flanagan, SCS, Range Conservationist: Provides overall leadership for the NRST in developing plans, schedules, and the collection of field data. Is responsible for the collection and reduction of all plant data in the study and will coordinate plant data processing with IRWET.

3. Michael Whited, SCS, Soil Scientist: Is responsible for collection and reduction of all soils data, site selection with respect to soils, and coordination with the National Soil Survey Laboratory (NSSL) and National Soil Mechanics (NSML) for laboratory analysis of soil samples. Will coordinate soils data processing with the IRWET, NSSL, and NSML staffs.

4. Kevin Hood, SCS, Hydrologic Technician: Is responsible for the collection and reduction of all hydrologic and erosion field data. Will coordinate hydrologic and erosion data processing with IRWET. Is responsible for the procurement, operation, maintenance, and repair of the NRST's equipment. Also directs the setup and tear-down of the sampling equipment and the purchasing of supplies to operate the equipment.

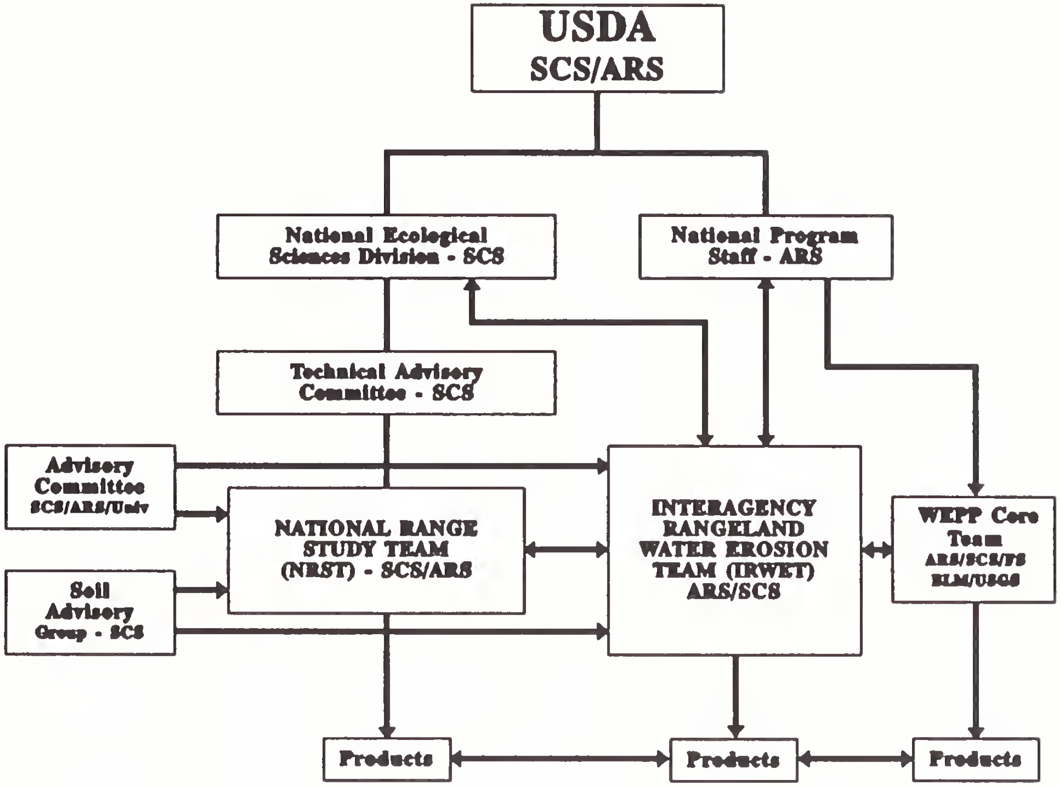


Figure 1. Organizational flow chart for Interagency Rangeland Water Erosion Team (IRWET) and National Range Study Team (NRST).

5. John Warner, SCS, Soil Scientist: Is responsible for assisting in the collection and reduction of all soils data and in site selection with respect to soil characteristics.

6. SCS student support, J. DuBose, J. Ostrander, and K. Schneider: Assist with field data collection and reduction.

Interagency Rangeland Water Erosion Team

1. W.H. Blackburn, ARS, Team Coordinator (Boise, ID): Will coordinate team research and technology transfer to insure timely delivery of finished products. Responsible for maintaining communications with ARS and SCS administrators, and model development and validation efforts. (Dr. Blackburn is now the ARS, Associate Area Director, Northern Plains Area - Fred Pierson and Ken Spaeth have assumed the coordinating role for the project)

2. Fred Pierson, ARS, Research Hydrologist (Boise, ID): Will act as IRWET team leader and coordinate activities between IRWET and NRST. Responsible for model enhancement and validation.

3. Mark Weltz, ARS, Research Hydrologist (Tucson, AZ): Responsible for model enhancement and validation. Will help coordinate activities between the WEPP Core Team and IRWET.

4. Kenneth Spaeth, SCS, Range Hydrologist (Boise, ID): Will coordinate transfer of data from the NRST to the IRWET and summarize data for SCS. Responsible for enhancement of the vegetation component of the model and in model validation and testing.

5. Dale Fox, SCS, Range Scientist (Tucson, AZ): Responsible for enhancement of the vegetation component of the model and in model validation and testing. Will help coordinate activities between the WEPP Core Team and IRWET.

6. Carol Franks, SCS, Soil Scientist (Lincoln,NE): Will serve as a liaison between IRWET and the SCS National Soil Survey Center to help coordinate activities.

7. Steven Van Vactor, ARS, Hydrologist (Boise, ID): Support enhancement and validation efforts of model components.

8. Method Odoemene, Research Associate, Boise State University (Boise, ID): Work with model validation.

9. Mario Tiscareno, Research Assistant, University of Arizona (Tucson, AZ): Support enhancement and validation efforts of model components.

10. Vacant, Post Doctoral Research Hydrologist, University of Idaho (Boise, ID): Work with IRWET personnel on model enhancement and validation efforts.

## ACTIVITIES AND ACCOMPLISHMENTS

National Range Study Team:

The NRST has completed three field seasons of data collection (1990, 1991 and 1992) in eight states (Nebraska, Texas, Wyoming, Kansas, Colorado, North Dakota, Idaho, and Arizona). A rotating boom rainfall simulator was procured, assembled, and modified to meet the objectives of the effort. The support field equipment includes three large capacity storage tanks, vehicles, field equipment, and a mobile field laboratory with diesel generator.

To date, the NRST has completed a total of 132 large and small plots on 22 sites representing a gradient of soils, vegetation, and varying degrees of management in eight states.

(See Appendix I for summary of field data collected in 1990 and 1991)

**Table 1.** Summary of completed sites, and large and small plots by state.

| Field Season | State | Sites | Large Plots | Small Plots |
|---|---|---|---|---|
| 1990 | NE | 2 | 12 | 12 |
| 1990 | TX | 2 | 12 | 12 |
| 1991 | WY | 3 | 18 | 18 |
| 1991 | KS | 3 | 18 | 18 |
| 1991 | CO | 3 | 18 | 18 |
| 1992 | ND | 3 | 18 | 18 |
| 1992 | WY | 2 | 12 | 12 |
| 1992 | ID | 2 | 12 | 12 |
| 1992 | AZ | 2 | 12 | 12 |
| Total | | 22 | 132 | 132 |

Other accomplishments include:

(1) participation in three working sessions to write and refine the implementation plan for the NRST and IRWET;

(2) provided field training in range hydrology to SCS national staff, technical center, state, area, and field office personnel;

(3) delivery of hydrology, vegetation, and soil data sets for Nebraska, Texas, Wyoming, Kansas and Colorado to IRWET;

(4) currently processing and reducing the 1992 data sets from North Dakota, Wyoming, Idaho, and Arizona;

(5) have begun the site selection process for 1993 which will include sites in Nevada, Colorado, California, and Utah;

(6) completed the following technology transfer activities:

A. Presented a slide presentation at the SCS employee meeting at the 1992 Society for Range Management Annual Meeting in Spokane, Washington;

B. Presented a brown bag seminar to the Midwest National Technical Center and National Soil Survey Center;

C. Completed a presentation on NRST to the University of Nebraska Range Club and Agronomy Club;

D. Hosted a field demonstration for the Society for Range Management and the Soil and Water Conservation Society (Wyoming Sections);

E. Provided a field demonstration of the study to the SCS, Midwest National Technical Center;

F. Completed a feature story on the NRST for the Society for Range Management's RANGELANDS magazine;

G. Prepared a news article for the North Dakota Professional Soil Classifiers Newsletter;

H. Completed interviews with the FARM & RANCH magazine in Idaho and the WESTERN FARMER STOCKMAN in Arizona;

I. Interviewed on KBBS Radio in Buffalo, Wyoming for 1 hour community show;

J. Interviewed and assisted with news articles in the Dunn County Herald and Wyoming Buffalo Bulletin;

K. Interviewed by KSGW Television from Sheridan, Wyoming for an evening news broadcast.

Interagency Rangeland Water Erosion Team:

An implementation plan for enhancement and further development of the rangeland hydrologic, erosion, and vegetation components of the WEPP model has been completed. Within the context of this plan, many research and model enhancement activities are now underway. Members of IRWET have also been successful in involving a number of

researchers at other locations in cooperative projects aimed at meeting the objectives outlined in the plan. The following is a summary of current IRWET projects and activities.

**Database Management**

* During the 1991 and 1992 field seasons, IRWET has worked in the field with the NRST in Wyoming, Kansas, Colorado, Idaho, and Arizona to become familiar with all aspects of the data collection process, and to help in making refinements in field methodology as needed. Field data from Nebraska, Texas, Wyoming, Kansas and Colorado has been summarized and is presented in Appendix I of this report.

* A functional database management system (Fox Pro 2.0) to facilitate the organization, reduction, and analysis of the NRST data, Tucson ARS/SCS rangeland hydrology data (1986, 1987, and 1988), and other related data sets which are pertinent to the project has been completed. All NRST field data from 1990 and 1991 has been entered and is now being error checked. The WEPP rangeland hydrologic and erosion data have also been entered. The companion vegetation and soils databases are currently being entered and will be completed by the summer of 1993.

**Research Projects**

1. Nancy Gulch Watershed Project

The objectives of this research are: 1) to test the algorithms used in the WEPP model for predicting Green-Ampt infiltration parameters, 2) determine if the WEPP model can predict runoff and erosion at different points on the landscape, and 3) determine if the modeling approaches used in WEPP are adequate for describing the spatial variability in hydrology and erosion which exists on rangelands.

**Project accomplishments include:** A rainfall simulation study was conducted on the Nancy Gulch watershed over a two year period. Runoff and erosion data were collected from four distinct soil/vegetation zones within the shrub-interspace complex using small irregularly shaped runoff plots. Runoff and erosion data were also collected from larger (10 X 35 ft) plots which contained mosaics of soil/vegetation zones. Accompanying soil texture, bulk density, soil moisture, organic carbon, aggregate stability, percent coarse rock fragments, canopy cover, ground cover, and surface roughness data were collected associated with each small and large plot. The proportion of each soil/vegetation zone within each large plot was also estimated. The large plots are being continuously monitored under natural rainfall conditions.

The data from this project have been collected and are now being analyzed. Preliminary analysis of the small and large plot rainfall simulation data indicates that the approach used in the model for estimating runoff and erosion for a uniform hillslope may not be adequate for describing the spatial variability which exists on shrub-dominated rangelands. The model currently predicts infiltration for a hillslope by taking an area weighted average of infiltration parameters for zones under canopy and within the interspace regions across the hillslope. This provides a single estimate of infiltration for the entire hillslope. The model then predicts runoff and erosion for the entire hillslope by calculating the rainfall excess produced by taking the rainfall amount and subtracting the amount of infiltration. Our data indicate that even if infiltration were predicted perfectly for each zone, an area weighted average across zones is still inadequate for estimating runoff and erosion over a larger integrated area. Infiltration is a point process and can be adequately described by the characteristics which exist at each discrete point. Therefore, infiltration for an integrated area can be estimated by taking an area weighted average of different locations. However, runoff and erosion are integrated processes over the landscape which can not be completely described by information at discrete points. Information is also needed about the processes as the runoff and sediment travel from one point to another down the hillslope. Thus, trying to predict runoff and erosion by using an area weighing scheme is in error unless all points on the hillslope are identical. This assumption may be adequate for some tilled agricultural lands,

but not for rangelands. Further investigation into small scale runoff and sediment routing processes will be necessary before current runoff and erosion predictive procedures can be improved.

2. Walnut Gulch Watershed Project

The objectives of this three year field project were: 1) to validate and enhance the hillslope and watershed versions of the WEPP model on rangelands, 2) to use optical, thermal and microwave data for characterization of soil moisture, and surface runoff patterns, 3) to develop methods of estimating and mapping surface albedo and evapotranspiration over rangelands, 4) estimating live and dead standing biomass, leaf area index, canopy cover, plant height, and density and spacing of plants, and 5) develop methods of integrating this remotely sensed information into default databases for hydraulic and erosion simulation models (i.e., KINEROS, RUSLE and WEPP).

**Project accomplishments include**: Live and dead standing biomass (by lifeform), leaf area index, canopy and ground cover, distribution of litter and rock on the soil surface, and the litter decomposition rate were evaluated 27 times over a 3 year period in both grazed and ungrazed conditions and on north and south facing aspects of the watershed. Twelve soil profiles (from 2.5 to 75 cm) were instrumented to measure the daily change in soil water content and soil temperature. Surface runoff was measured at 3 locations within the 60 ha experimental watershed. Runoff was measured from a hillslope (1 ha), from the upper 20 ha of the watershed, and at the outlet of the 60 ha watershed. Sediment samples were collected with a integrated depth sampler from the hillslope watershed. Runoff from the outlet of the watershed was collected in a gauged stock pond. Hourly air temperature, solar radiation, wind speed, wind direction, and relative humidity were measured. Hourly evapotranspiration was estimated with a "Gill" Anemometer. Rainfall depth, intensity, and duration were measured on the watershed with 3 weighing raingages. Remotely sensed information was collected throughout the experiment to assess the spatial and temporal density, canopy cover height, and leaf area index of the vegetation.

Data reduction, analysis, and interpretation is currently in progress. Expected results are listed below:

1. Spatial distribution of litter and rocks on a semiarid desert grassland;
2. Temporal distribution of litter and rocks on a semiarid desert grassland;
3. Water balance of a semiarid desert grassland;
4. Estimating rangeland plant growth with the WEPP model;
5. Estimating litter decomposition on a semiarid desert grassland;
6. Rangeland WEPP hillslope and watershed model validation;
7. Sensitivity of rangeland WEPP to plant growth and management practices;

In addition, NRST field data will provide the following:

1. Spatial distribution of litter and rocks from 30 rangeland plant communities;
2. Root distribution for 30 rangeland plant communities;
3. Root/shoot ratios for 30 rangeland plant communities; and
4. Leaf area index for selected rangeland plants.

3. <u>Gradient Analysis of Environmental and Hydrologic Variables as Related to the Rangeland WEPP Model.</u>

The major objectives of this research project are: 1) to investigate plant community, hydrologic, and environmental gradients from the National Range Study Team grassland and shrub sites; 2) Identify variables which can be used to improve estimates of hydrologic and erosion parameters in the Rangeland WEPP model. Gradient analysis and ordination procedures are useful in detecting relationships between species composition and the environment. This information can also be used by SCS to update the National Range Handbook, revise range site descriptions, and publish SCS technical notes.

**Project accomplishments include:** A gradient analysis was conducted on rangeland data sets which include NRST sites from Nebraska, Texas, Wyoming, Kansas, Colorado, as well as other locations. This project will also examine plant community, hydrologic, and environmental gradients within the vegetation treatments for individual states and for all the sites combined. This effort will identify the dynamic response of each site's hydrologic characteristicswith respect to differences in plant community structure, species composition, and environmental variables. A gradient analysis was also made on the Rauzi et al. (1968) data set to evaluate rangeland soil, vegetation, and hydrologic differences among 25 range sites in the six Northern and Central Great Plains States of Montana, North Dakota, South dakota, Nebraska, and Kansas. This data set was collected during the period 1952 to 1964 by the SCS-Soil and Water Conservation Research Division and the Agricultural Research Service.

4. <u>Spatial Pattern Analysis of Rangeland Vegetation: Applications to Hydrologic and Erosion Processes.</u>

The objective of this research effort is to develop a more ecological approach in identifying and mathematically defining spatial patterns in vegetation for use in parameterizing the Green-Ampt and erosion equations for the rangeland components of WEPP.

**Project accomplishments include:** In 1992, spatial pattern data was collected at the NRST Buffalo Wyoming site, NRST Blackfoot Idaho site, Summit, Nancy Gulch, Quonset, Lower Sheep, and Reynolds Mountain sites--Reynolds Creek Watershed. Several data collection techniques were used: quadrant variance and distance sampling techniques. The data is currently being processed in the laboratory and entered into the computer.

**Cooperative Research Projects**

IRWET has been successful in involving a number of university scientists in cooperative projects aimed at meeting the goals and objectives of the IRWET effort. The following is a list of cooperators with a brief description of the respective project.

1. **Dr. J. Dobrowolski**, Utah State University - Dr. Dobrowolski has collected extensive data on the influence of different surface soil crusts on infiltration and saturated hydraulic conductivity. IRWET is working with him to develop algorithms to describe this relationship and incorporate them into the WEPP model.

2. **Dr. W. Rawls and Dr. R. Savabi** with the ARS Hydrology Laboratory in Beltsville, MD and ARS National Soil Erosion Laboratory in West Lafayette, IN, respectively - Dr. Rawls is the author of the infiltration routines used in the model and Dr. Savabi is responsible for the WEPP model code for infiltration and runoff processes. IRWET has solicited their cooperation on the Nancy Gulch Project discussed above to insure that findings are consistent with what has been done in the past and what will be done in the future.

3. **Dr. R. Sosebee**, Texas Tech University - Dr. Sosebee has a Ph.D. graduate student studying the spatial variability of hydrologic processes within a perennial Broom Snakeweed plant community. This will provide IRWET with data to build WEPP parameter data sets for Broom Snakeweed communities.

4. **Dr. B. Allen-Diaz**, University of California at Berkeley - IRWET is working with Dr. Allen-Diaz on instrumenting an annual grassland watershed to look at the influence of annual vegetation on hydrologic processes. She also has a Ph.D. graduate student working on the spatial and temporal variability of hydrologic properties under different types of vegetation. This type of data will allow IRWET to validate WEPP and build model parameter data sets for annual grassland plant communities.

**WEPP Model Validation**

The WEPP Core Team coordinated out of the ARS, National Soil Erosion Laboratory will release the official version of the WEPP model for validation in March, 1993. We are currently producing WEPP model data sets for the event based version of the WEPP hillslope model based on 1986-1988 ARS/SCS and NRST rainfall simulation data sets. These data sets will be used to validate portions of the model and will be delivered to SCS personnel for use in running the model. It is anticipated that results from comparing observed and model predicted soil erosion values by field site will be available in 1993 and that reports of the results will be delivered to the cooperating states.

The rangeland hydrology and erosion components of the model code have been isolated and are now ready for validation. To cooperate with the objectives of the WEPP Core Team we will wait to validate these components until they decide if contemplated modifications to these components are completed or abandoned.

Members of IRWET have also been involved in validation and use of the Simulation of Production and Utilization on Rangelands (SPUR) model. The model was validated using hydrology and erosion data from the Bad River Watershed in South Dakota.

Other accomplishments include graduate level training for the IRWET Team Leader in Systems Engineering. This training has and will continue to aid in project planning and in model enhancement and validation efforts.

**Technology Transfer**

IRWET has been involved in numerous activities aimed at transferring information and technology to SCS, university and international personnel. The following is a list of meetings attended and people contacted by IRWET personnel.

1. Attended five WEPP Core Team Meetings and delivered presentations on IRWET activities.

2. SCS/ARS Plant growth model workshop.

3. Seven presentations presented at the following meetings:
   * Society for Range Management Annual Meeting, Spokane, WA.
   * Soil Science Society of America Annual Meeting, Minneapolis, MN.

4. Presented seminar at Colorado State University, "New horizons in predicting soil erosion", Oct. 1992.

5. Attend two SCS National Range Conservationist meetings.

6. Presented seminars to the following groups or individuals on the IRWET effort:
   * SCS personnel, Technology Information Services Division, Fort Collins, Co,
   * Personnel from the Range Department at Texas A&M University,
   * Dr. A.S. Rao, Division of Resource Management, Central Arid Zone Research Institute, Jodhpur, India,
   * Bureau of Land Management Workshop, Boise, ID,
   * SCS Idaho State Office.

7. Worked with SCS State offices in South Dakota, Texas, and Wyoming on the transfer of WEPP and SPUR technology.

8. Sponsored two symposia:
   * "Variability in Rangeland Water Erosion Processes" at the Soil Science Society of America Annual Meeting, Nov. 1-6, 1992, Minneapolis, MN,
   * "Predicting Rangeland Hydrologic and Erosion Processes" at the Society for Range Management Annual Meeting, Feb. 13-19, 1993, Albuquerque, MN.

9. A list of 1991/1992 IRWET publications can be found in Appendix II.

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# APPENDIX I

NRST Data Summaries

This appendix contains summaries of vegetation, soils and hydrologic data for the following states and locations. All summaries are made on the basis of site codes.

| State | County | Site Code | Date Sampled |
|---|---|---|---|
| Nebraska | Saunders | B1 | June, 1990 |
| Nebraska | Saunders | B2 | June, 1990 |
| Texas | Bosque | C1 | July, 1990 |
| Texas | Bosque | C2 | July, 1990 |
| Kansas | Greenwood | E1 | June, 1991 |
| Kansas | Greenwood | E2 | June, 1991 |
| Kansas | Greenwood | E3 | June, 1991 |
| Colorado | Washington | F1 | September, 1991 |
| Colorado | Washington | F2 | September, 1991 |
| Colorado | Logan | F3 | September, 1991 |
| Wyoming | Weston | G1 | July, 1991 |
| Wyoming | Weston | G2 | July, 1991 |
| Wyoming | Weston | G3 | July, 1991 |

# NEBRASKA Data Summary

Range Site Description

The potential natural vegetation of these study sites is native tallgrass prairie and is dominated by tall grasses. About 80% of the total composition is comprised of grasses, 5% grasslike plants, 10% forbs, and 5% shrubs. Big bluestem, indiangrass, little bluestem, porcupine-grass, sideoats grama, and switchgrass are the dominant species making up 75% of more of the total annual production. Blue grama, Kentucky bluegrass, prairie dropseed, prairie junegrass, Scribner panicum, tall dropseed, sedges, numerous native forbs, and some shrubs are also important plants in this site. Some typical forbs are black sampson, yarrow, Maximilian sunflower, silverleaf scurfpea, cudweed sagewort, western marbleseed, catclaw sensitivebriar, aromatic aster, prairie onion, plains wildindigo, gayfeathers, and many others. Shrubs can include buckbrush, Arkansas rose, leadplant, sunshine rose, western snowberry, and Jerseytea ceanothus.

Two sites were sampled in Nebraska. Location B1 was sampled, using the double-sampling method, and found to be in poor range condition (14.5 percent). Out of the two locations, B1 had very few native grasses present compared to B2. Kentucky bluegrass was the dominant plant species. The sample plots on B1 showed no evidence of indiangrass and porcupinegrass whereas B2 had 8.6 percent indiangrass and 12.8 percent porcupinegrass. The average annual production for B1 was 983.3 pounds per acre and the average amount of litter on B1 was 574 pounds per acre. The estimated bare ground on B1 was 11.7 percent.

Location B2 was sampled, using the double-sampling method, and found to be in fair range condition (44.4 percent). The average annual production for B2 was 3,424.2 pounds per acre and the average amount of litter on B2 was 766.7 pounds per acre. The estimated bare ground on B2 was 9.2 percent.

Table 1. Nebraska Site Characteristics.

| Variable | B1 Nebraska<br>Heavy Grazing Use | B2 Nebraska<br>Native Hayland |
|---|---|---|
| Range Site | Clay loam | Clay loam |
| Avg. Annual Precip. (in) | 25 to 34 | 25 to 34 |
| Slope (%) | 10 | 11 |
| Elevation (ft) | 1500 | 1400 |
| Aspect | West | East |
| Potential Climax Vegetation | Big bluestem/little bluestem | Big bluestem/little bluestem |
| Range Condition | Poor | High Good |
| Dominant Plants | Kentucky bluegrass<br>Western ragweed<br>Dandelion<br>Horseweed | Big Bluestem<br>Indiangrass<br>Porcupine-grass<br>Sideoats grama |
| Primary Use | Cow/calf operation; pasture is used as a drylot calving area spring through summer | Native hayland harvested in mid July |
| Management History | No fertilizer, brush control, or burning | No fertilizer, brush control, or burning |

Table 2. Nebraska Vegetation Data.

| Variable | B1 Nebraska Heavy Grazing Use | B2 Nebraska Native Hayland |
|---|---|---|
| Grass Canopy Cover (CC) | 9.38 | 10.20 |
| Forb CC % | 17.82 | 7.17 |
| Shrub/H. Shrub CC % | 0.00 | 5.30 |
| Standing Dead CC% | 0.00 | 0.00 |
| Cacti CC% | 0.00 | 0.00 |
| Basal Vegetation % | 6.66 | 2.38 |
| Cryptogam <1cm ht. CC % | 0.00 | 0.00 |
| Cryptogam >1cm ht. CC % | 0.00 | 0.00 |
| Litter % | 72.86 | 86.02 |
| Bare Soil % | 20.41 | 11.60 |
| Rock % | 0.00 | 0.00 |
| Production (lbs/ac) | 983.3 | 3424.0 |
| Litter (lbs/ac) | 574.0 | 767.0 |
| Random Roughness (std dev.) | 9.93 | 12.17 |

# NARRATIVE PEDON DESCRIPTION

Pedon: Burchard
Soil Survey Number S90-NE-155-060
Location: Saunders County, Nebraska
2050' N and 235' E of the SW corner of Section 29, T.13N., R.5E.
Latitude: 41-03-58-N
Physiography: Hillside or mountainside in glaciated uplands
Geomorphic Position: backslope sideslope
Microrelief: on middle third of component
Slope: 10% convex northwest facing
Precipitation: 71 cm - Udic Moisture Regime.
MLRA: 106 Nebraska and Kansas Loess-Drift Hills
Air Temperature: Ann: 11 Summ: Win:
Soil Temperature: Ann: 10 Summ: Win:
Drainage: Well drained
Stoniness: Erosion or Deposition: None
Particle Size Control Section: 30 to 81 cm
Parent Material: glacial drift from mixed-calcareous material
Classification: Fine-loamy, mixed, mesic Typic Argiudoll
Diagnostic Horizons: 0 to 30 cm Mollic, 30 to 109 cm Argillic
Described By: Steve Scheinost and Lester Brockman.
Over grazed pasture - heavy continuous use. Associated soils are Judson and Pawnee.

NSSL Pedon Number: 90P0688
Print Date: 01/13/92
Longitude: 076-53-18-W
Elevation: 448 m MSL
Land Use: Pasture land and native pasture
Runoff: Moderate
Sample Date: 6/90

A1 -- 0 to 3 cm; very dark brown (10YR 2/2) crushed moist silt loam; moderate fine granular structure; very friable; many very fine and fine roots throughout; abrupt smooth boundary.
90P4051

A2 -- 3 to 5 cm; black (10YR 2/1) crushed moist clay loam; moderate fine platy structure parting to moderate fine granular; friable; common very fine and fine roots throughout and many very fine and fine roots between peds; abrupt smooth boundary.
90P4052

A3 -- 5 to 18 cm; very dark grayish brown (10YR 3/2) crushed moist clay loam; weak fine prismatic structure parting to strong fine subangular blocky; friable; common very fine and fine roots throughout; very few iron stains; clear wavy boundary.
34% clay
90P4053

AB -- 18 to 30 cm; very dark grayish brown (10YR 3/2) crushed moist clay loam; weak fine prismatic structure parting to moderate medium subangular blocky; friable; very fine and fine roots between peds and very fine and fine roots throughout; fine tubular pores; very few iron stains; clear wavy boundary.
38% clay
90P4054

Bt -- 30 to 48 cm; dark grayish brown (10YR 4/2) crushed moist clay loam; moderate medium prismatic structure parting to moderate medium subangular blocky; firm; very fine roots between peds; very fine tubular pores; patchy distinct organic coats on faces of peds and in pores and patchy distinct clay films on faces of peds and very few patchy distinct iron stains; gradual smooth boundary.
39% clay
90P4055

Btk1 -- 48 to 71 cm; 30% grayish brown (10YR 5/2) exterior, 30% olive brown (2.5Y 4/4) exterior and 40% yellowish brown (10YR 5/6) exterior moist clay loam; common fine distinct mottles; moderate medium prismatic structure parting to moderate medium subangular blocky; firm; very fine roots in cracks; very fine tubular pores; patchy distinct organic coats on faces of peds and in pores and patchy distinct clay films on faces of peds and very few patchy distinct iron stains; coarse irregular soft masses of lime; strongly effervescent continuous; clear irregular boundary.
39% clay
90P4056

Btk2 -- 71 to 91 cm; 30% dark yellowish brown (10YR 4/6) exterior, 30% olive brown (2.5Y 4/4) exterior and 40% grayish brown (2.5Y 5/2) exterior moist clay loam; few fine prominent mottles; moderate medium prismatic structure parting to moderate medium angular blocky; firm; very fine roots in cracks; very fine tubular pores; very few iron stains; common medium irregular soft masses of iron-manganese and medium and coarse irregular soft masses of lime; strongly effervescent continuous; clear irregular boundary.
39% clay
90P4057

Btk3 -- 91 to 109 cm;.
subsample
90P4058

BC --109 to 140 cm; 20% olive brown (2.5Y 4/4) exterior, 30% brown to dark brown (7.5YR 4/4) exterior and 50% light brownish gray (2.5Y 6/2) exterior moist clay; few fine prominent mottles; medium prismatic structure parting to moderate medium angular blocky; firm; very few iron stains; common medium irregular soft masses of iron-manganese and medium and coarse irregular soft masses of lime; strongly effervescent continuous; clear irregular boundary.
42% clay
90P4059

C --140 to 152 cm; 20% olive brown (2.5Y 4/4) exterior, 30% brown to dark brown (7.5YR 4/4) exterior and 30% pinkish gray (7.5YR 6/2) exterior moist clay; few fine prominent mottles; weak coarse prismatic structure; very firm; very few iron stains; common medium irregular soft masses of iron-manganese and medium and coarse irregular soft masses of lime; strongly effervescent continuous.
42% clay
90P4060

## NARRATIVE PEDON DESCRIPTION

Pedon: Burchard
Soil Survey Number S90-NE-155-061
Location: Saunders County, Nebraska
2360' S and 2000' W of the NE corner of Section 32, T.13N., R.5E.
Latitude: 41-03-14-N
Physiography: Hillside or mountainside in glaciated uplands
Geomorphic Position: backslope sideslope
Microrelief: on middle third of component
Slope: 13% convex east facing
Precipitation: 71 cm - Udic Moisture Regime.
MLRA: 106 Nebraska and Kansas Loess-Drift Hills
Air Temperature: Ann: 11 Summ: Win:
Soil Temperature: Ann: 10 Summ: Win:
Drainage: Well drained
Stoniness: Erosion or Deposition: None
Particle Size Control Section: 41 to 91 cm
Parent Material: glacial drift from mixed-calcareous material
Classification: Fine-loamy, mixed, mesic Typic Argiudoll
Diagnostic Horizons: 0 to 28 cm Mollic, 41 to 102 cm Argillic, 53 to 102 cm Calcic
Described By: Steve Scheinost and Steve Hartung.

NSSL Pedon Number: 90P0693
Print Date: 01/13/92
Longitude: 096-52-37-W
Elevation: 435 m MSL
Land Use: Pasture land and native pasture
Runoff: Moderate
Sample Date: 6/90

Tall grass pasture -- mowed for hay, seldom grazed. Associated soils are Judson and Pawnee.

A1 -- 0 to 5 cm; black (10YR 2/1) crushed moist loam; weak fine crumb structure; friable; many fine and medium roots throughout and fine to coarse roots throughout; 5 percent pebbles; abrupt smooth boundary.
24% clay
90P4079

A2 -- 5 to 15 cm; very dark gray (10YR 3/1) crushed moist loam; weak fine granular structure; friable; many very fine and fine roots throughout and medium and coarse roots throughout; 5 percent pebbles; clear smooth boundary.
27% clay
90P4080

A3 -- 15 to 28 cm; very dark grayish brown (10YR 3/2) crushed moist clay loam; weak fine prismatic structure parting to moderate fine subangular blocky; friable; many very fine and fine roots throughout and medium and coarse roots throughout; 5 percent pebbles; clear wavy boundary.
30% clay
90P4081

AB -- 28 to 41 cm; dark grayish brown (10YR 4/2) crushed moist clay loam; weak medium prismatic structure parting to moderate medium subangular blocky; friable; common fine and medium roots throughout and medium roots throughout; discontinuous faint organic coats on faces of peds; 5 percent pebbles; clear wavy boundary.
31% clay
90P4082

Bt -- 41 to 53 cm; olive brown (2.5Y 4/4) crushed moist clay loam; few fine distinct and common medium faint mottles; weak medium prismatic structure parting to moderate medium subangular blocky; firm; common fine and medium roots throughout; patchy clay films on faces of peds; common fine irregular soft masses of iron-manganese; strongly effervescent continuous; 5 percent pebbles; clear wavy boundary.
35% clay
90P4083

Btk1 -- 53 to 69 cm; brown to dark brown (10YR 4/3) exterior and dark brown (10YR 3/3) crushed moist clay loam; few fine distinct, few fine prominent and common fine distinct mottles; weak coarse prismatic structure parting to moderate medium angular blocky; firm; common very fine and fine roots throughout; very fine and fine tubular pores; patchy clay films on faces of peds; common fine irregular soft masses of iron-manganese; strongly effervescent continuous; 5 percent pebbles; gradual wavy boundary.
36% clay
90P4084

Btk2 -- 69 to 86 cm; 40% brown to dark brown (10YR 4/3) exterior, 60% grayish brown (2.5Y 5/2) exterior and dark yellowish brown (10YR 4/4) crushed moist clay loam; few medium prominent, few coarse prominent and common coarse prominent mottles; moderate medium prismatic structure parting to moderate medium and coarse angular blocky; firm; common very fine and fine roots throughout and medium roots throughout; common very fine and fine tubular pores; continuous clay films on vertical and horizontal faces of

peds; common fine and medium irregular soft masses of iron-manganese and common fine and medium irregular soft masses of lime; strongly effervescent continuous; 5 percent pebbles; diffuse wavy boundary.
38% clay
90P4085

Btk3 -- 86 to 102 cm;.
subsample
90P4086

BC --102 to 127 cm; 40% brown to dark brown (10YR 4/3) exterior and 60% grayish brown (2.5Y 5/2) exterior moist clay; few medium prominent, few coarse prominent and common coarse prominent mottles; weak coarse prismatic structure parting to moderate medium angular blocky; very firm; very fine and fine roots in cracks and medium roots in cracks; continuous clay films on vertical and horizontal faces of peds; common fine and medium irregular soft masses of iron-manganese and common fine and medium irregular soft masses of lime; strongly effervescent continuous; 5 percent pebbles; clear wavy boundary.
42% clay
90P4087

C --127 to 152 cm; light brownish gray (2.5Y 6/2) exterior moist clay; few coarse prominent and common medium and coarse prominent mottles; massive; very firm; fine and medium irregular soft masses of lime; slightly effervescent continuous; 1 percent pebbles.
48% clay
90P4088

Table 3. Selected soil horizon characteristics of the master soil pedon sampled for site B1, Nebraska - Burchard clay loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragments (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-3 | 28.1 | 41.0 | 30.9 | SIL | . | 10.09 | Tr | . | 24.6 |
| A2 | 3-5 | 26.2 | 42.6 | 31.2 | CL | . | 4.32 | 3 | . | 18.1 |
| A3 | 5-18 | 27.1 | 36.3 | 36.6 | CL | 1.56 | 2.32 | 2 | 28.1 | 16.4 |
| AB | 18-31 | 28.8 | 31.8 | 39.4 | CL | 1.76 | 1.25 | 2 | 26.8 | 17.7 |
| Bt | 31-49 | 30.1 | 31.1 | 38.8 | CL | 1.81 | 0.71 | 2 | 25.4 | 16.8 |
| Btk1 | 49-72 | 29.2 | 37.9 | 32.9 | CL | 1.78 | 0.32 | 2 | 20.9 | 13.4 |
| Btk2 | 72-92 | 30.1 | 37.3 | 32.6 | CL | 1.71 | 0.14 | 4 | 21.7 | 13.8 |
| Btk3 | 92-110 | 29.4 | 38.6 | 32.0 | CL | 1.83 | 0.06 | 9 | 20.9 | 15.2 |
| BC | 110-140 | 31.1 | 37.0 | 31.9 | C | 1.90 | 0.02 | 2 | 23.3 | 14.8 |
| C | 140-160 | 32.8 | 33.6 | 33.6 | C | 1.73 | 0.03 | 3 | 21.8 | 15.9 |

[1]Key to texture; SIL=Silty loam, CL=Clay-loam, C=Clay.

Table 4. Selected soil horizon characteristics of the master soil pedon sampled for site B2, Nebraska - Burchard clay loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragments (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-5 | 35.0 | 37.8 | 27.2 | L | 1.02 | 4.57 | 2 | 39.3 | 18.3 |
| A2 | 5-16 | 38.3 | 32.2 | 29.5 | L | 1.43 | 2.39 | 6 | 23.6 | 14.8 |
| A3 | 16-28 | 35.8 | 30.5 | 33.7 | CL | 1.63 | 1.80 | 3 | 27.1 | 16.4 |
| AB | 28-40 | 34.2 | 30.8 | 35.0 | CL | 1.66 | 1.32 | 1 | 27.1 | 16.6 |
| Bt | 40-53 | 32.7 | 35.2 | 32.1 | CL | 1.68 | 0.78 | 4 | 20.3 | 13.9 |
| Btk1 | 53-68 | 32.3 | 37.0 | 30.7 | CL | 1.75 | 0.54 | 5 | 19.7 | 13.7 |
| Btk2 | 68-86 | 30.5 | 39.6 | 29.9 | CL | 1.80 | 0.34 | 6 | 18.9 | 13.6 |
| Btk3 | 86-102 | 31.2 | 38.5 | 30.3 | CL | 1.88 | 0.19 | 3 | 20.2 | 14.2 |
| BC | 102-127 | 31.5 | 37.7 | 30.8 | C | 1.86 | 0.09 | 3 | 22.4 | 15.3 |
| C | 127-152 | 31.0 | 38.0 | 31.0 | C | 1.93 | 0.07 | 4 | 20.5 | 15.4 |

[1]Key to texture; CL=Clay-loam, C=Clay.

Table 5. Average soil bulk density measured at 2 depths by the complience cavity method before rainfall simulation began and 24 hours after the very wet rainfall simulation ended for sites B1 and B2 in Nebraska.

| Site | Sampled | Depth (cm) | Bulk Density ($g/cm^3$) | Sample Size |
|---|---|---|---|---|
| B1 | Before Dry | 0.0-2.5 | 0.92 | 6 |
| | | 2.5-10.0 | 1.68 | 6 |
| | After Very Wet | 0.0-2.5 | 0.66 | 6 |
| | | 2.5-10.0 | 1.31 | 6 |
| B2 | Before Dry | 0.0-2.5 | 1.04 | 6 |
| | | 2.5-10.0 | 1.20 | 6 |
| | After Very Wet | 0.0-2.5 | 0.70 | 6 |
| | | 2.5-10.0 | 1.09 | 6 |

Table 6. Average root biomass measured at 2 depths for sites B1 and B2 in Nebraska.

| Site | Landscape Position | Depth (cm) | Root Biomass (kg/ha) | Sample Size |
|---|---|---|---|---|
| B1 | Basal | 0.0-2.5 | 3700.56 | 6 |
| | | 2.5-10.0 | 205.14 | 6 |
| B2 | Basal | 0.0-2.5 | 732.50 | 6 |
| | | 2.5-10.0 | 173.75 | 6 |

Table 7. Average hydrologic characteristics of dry and wet antecedent moisture condition rainfall simulation runs for sites B1 and B2 in Nebraska.

| Site | Cumulative Runoff (mm) | Cumulative Infiltration (mm) | Cumulative Sediment Yield (kg/ha) | Runoff Rate (mm/hr) | Infiltration Rate (mm/hr) | Sediment Yield Rate (kg/ha/hr) |
|---|---|---|---|---|---|---|
| At 60 Minutes During Dry Runs | | | | | | |
| B1 | 25.14 | 25.32 | 203.74 | 34.93 | 9.09 | 80.76 |
| B2 | 0.05 | 51.02 | 0.63 | 0.63 | 52.61 | 4.07 |
| At 30 Minutes During Wet Runs | | | | | | |
| B1• | 6.82 | 9.61 | 26.61 | 27.72 | 3.45 | 37.99 |
| B2 | 1.02 | 25.02 | 13.28 | 9.84 | 41.87 | 122.43 |

• Values reported are averages over 30 minutes or until rainfall ended if run time was less than 30 minutes.

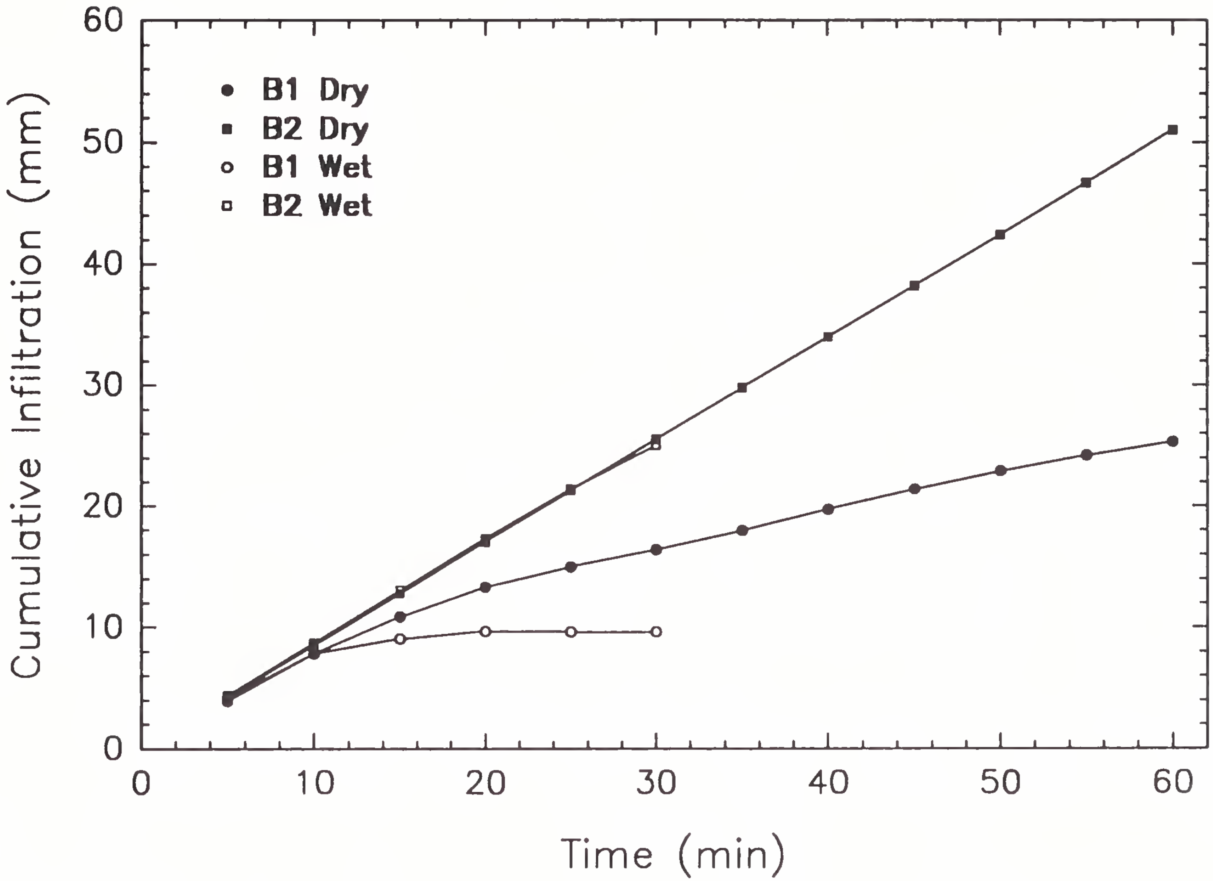


Figure 1. Cumulative infiltration for sites B1 and B2 in Nebraska.

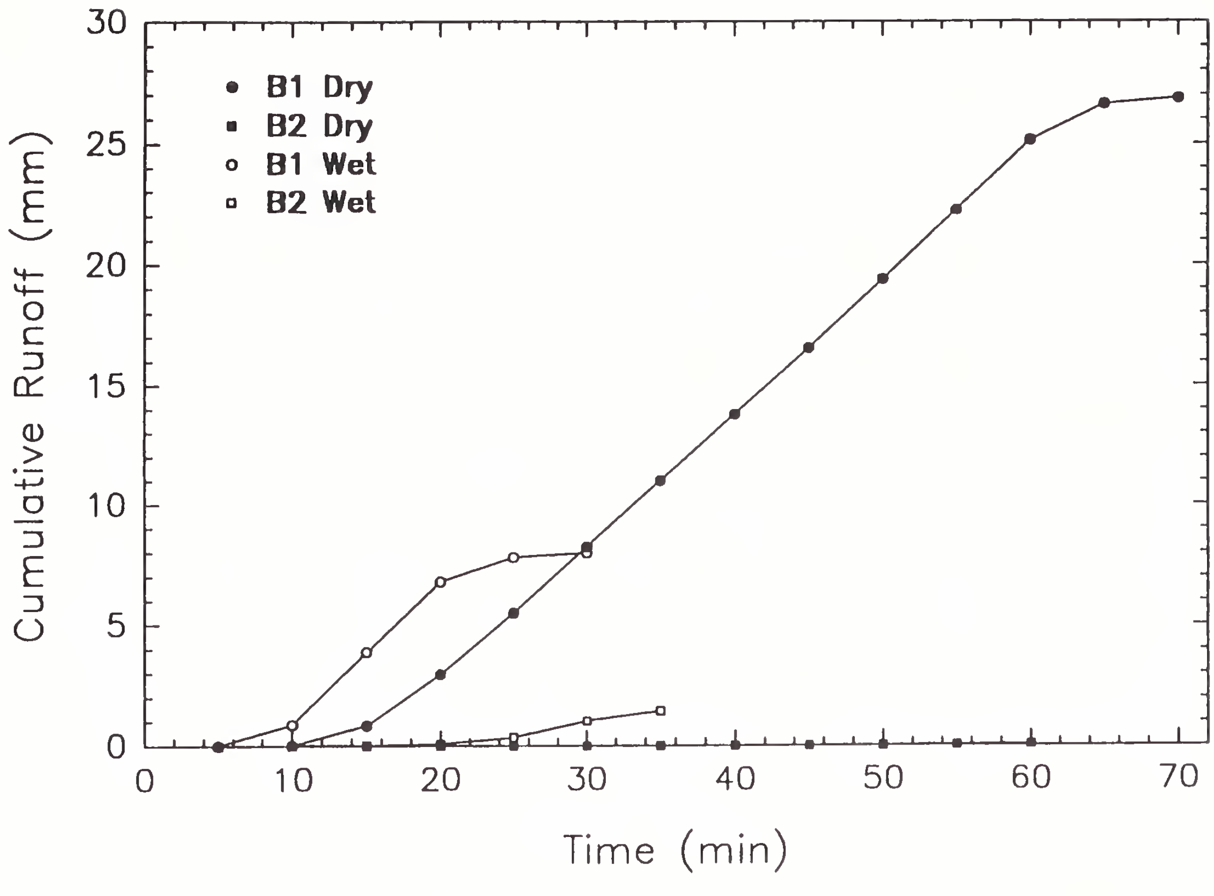


Figure 2. Cumulative runoff for sites B1 and B2 in Nebraska.

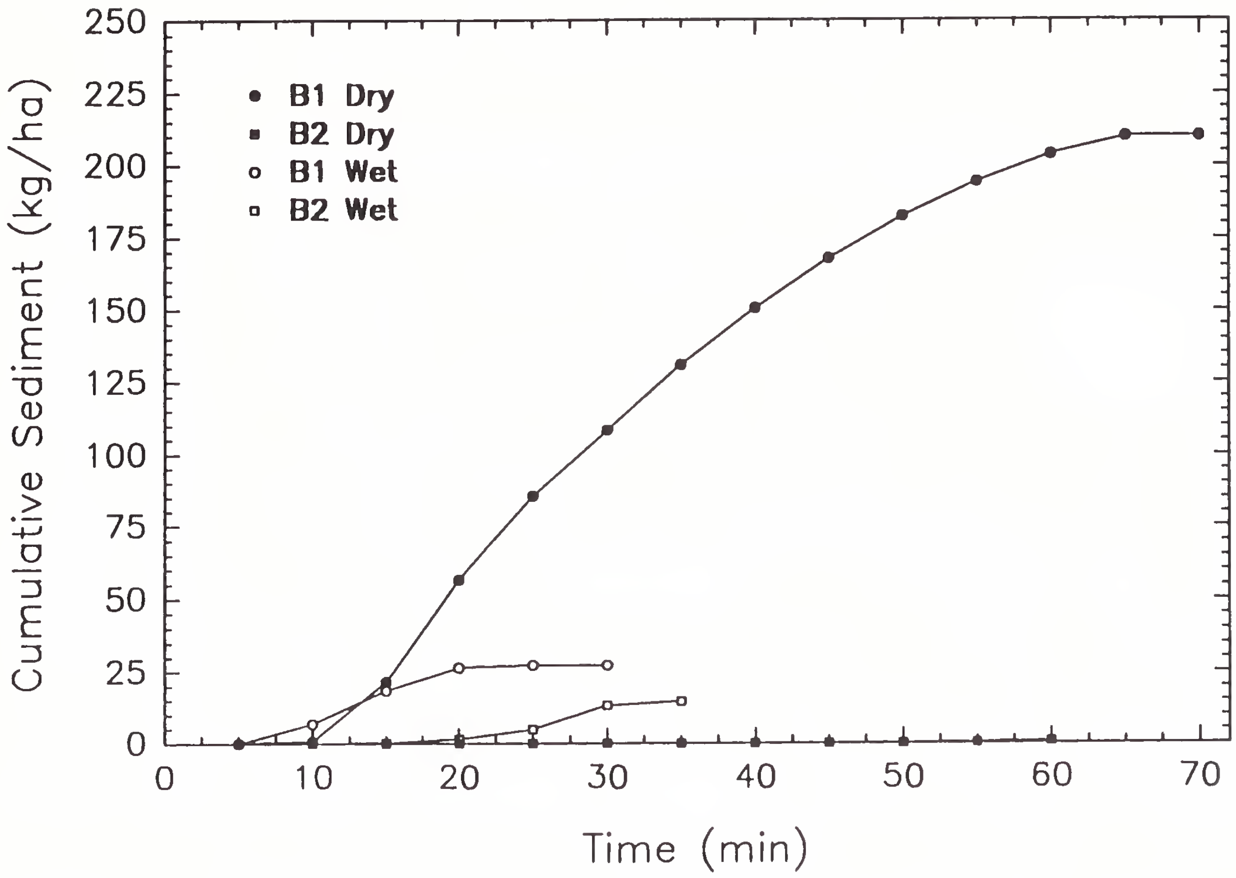


Figure 3. Cumulative sediment yield for sites B1 and B2 in Nebraska.

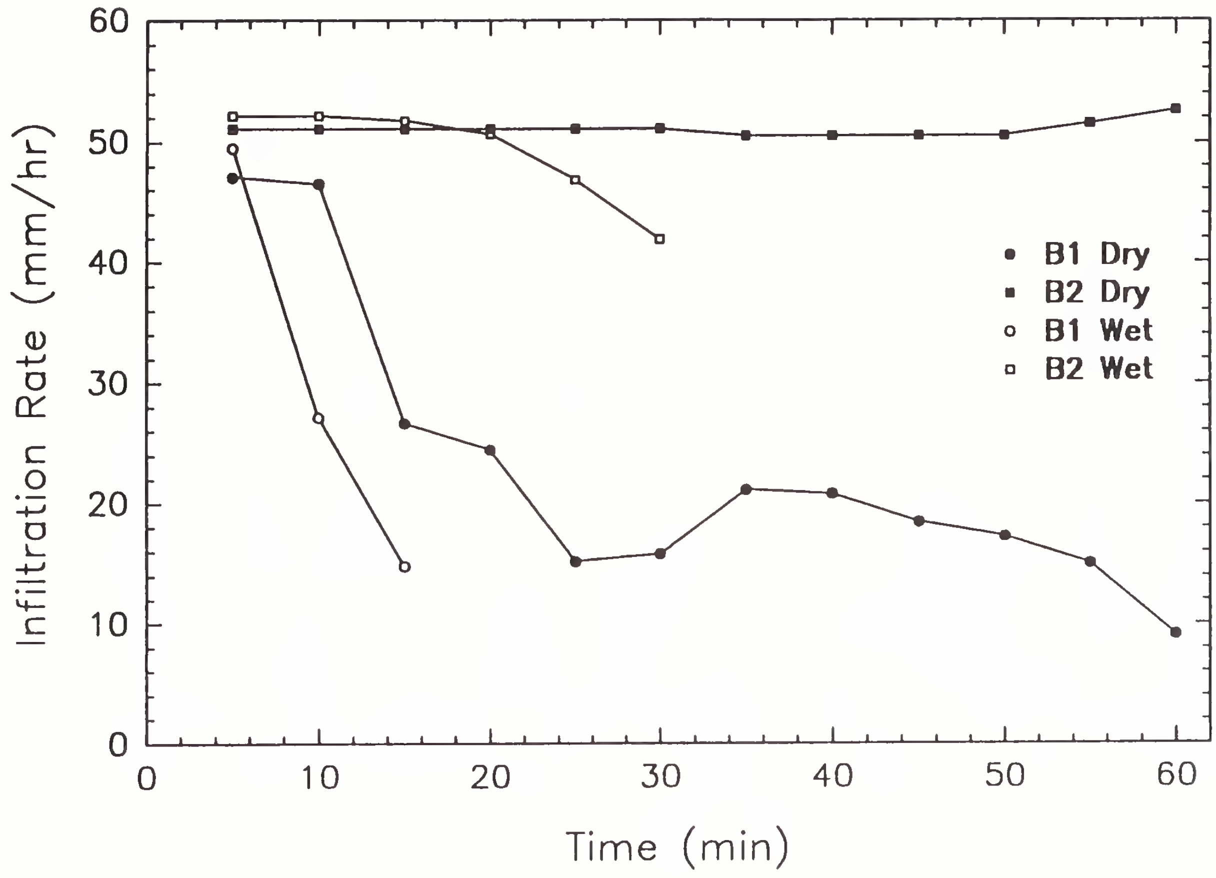


Figure 4. Instantaneous infiltration rate for sites B1 and B2 in Nebraska.

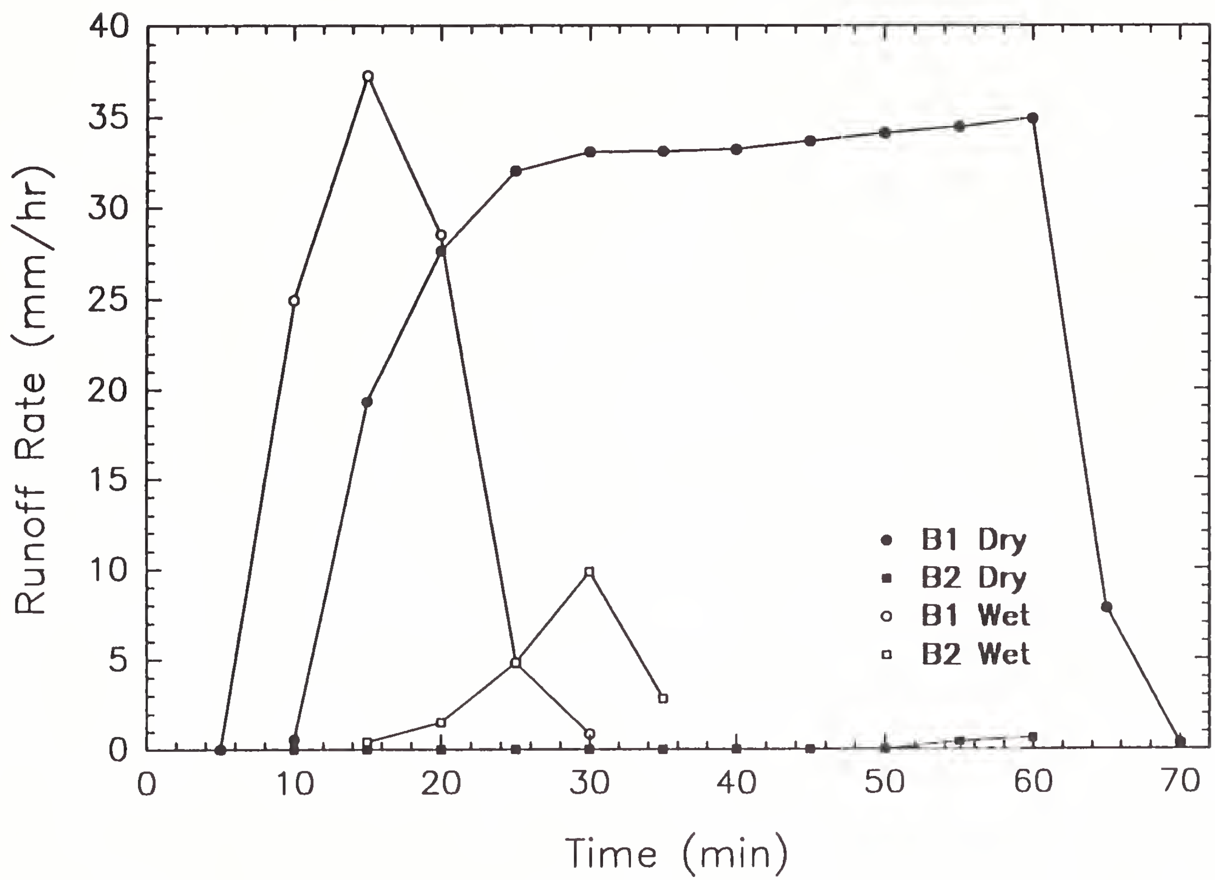


Figure 5. Instantaneous runoff rate for sites B1 and B2 in Nebraska.

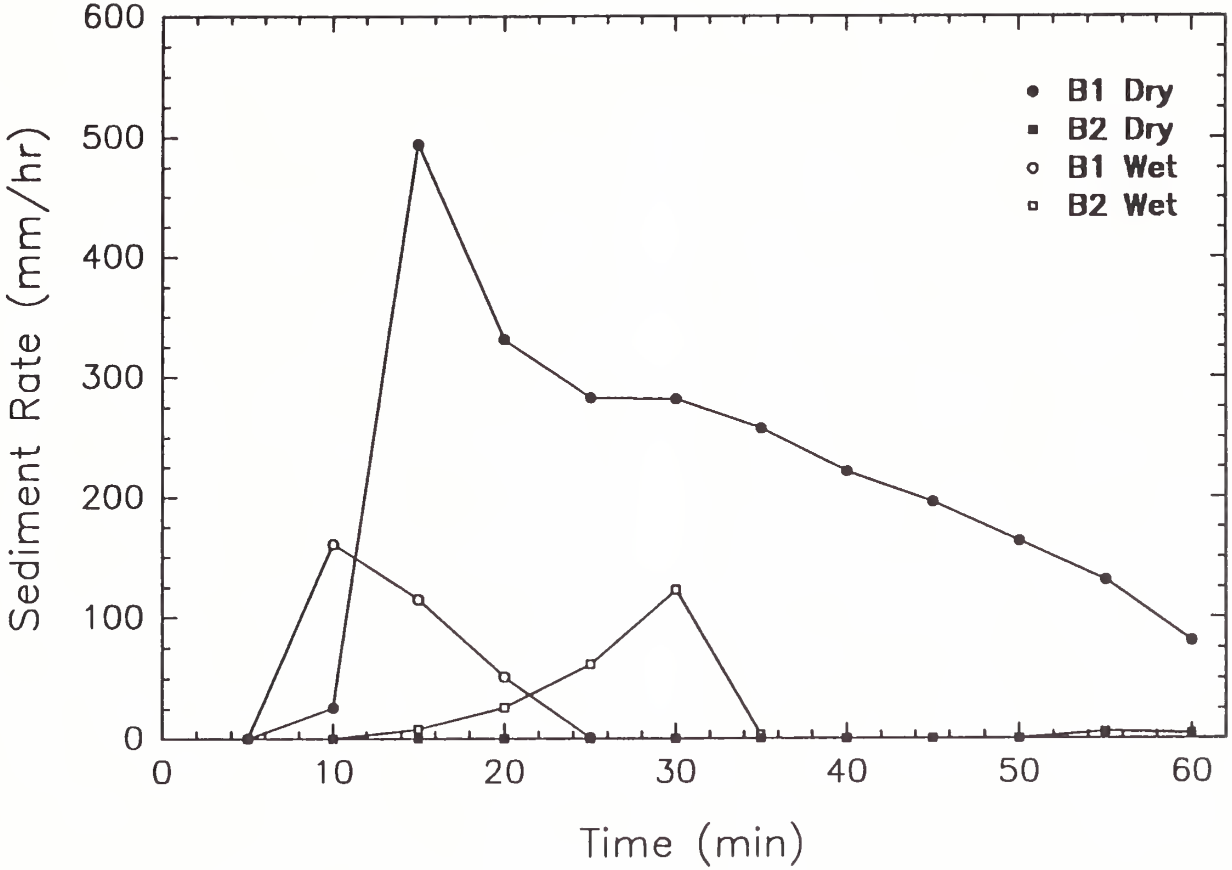


Figure 6. Instantaneous sediment yield rate for sites B1 and B2 in Nebraska.

# TEXAS Data Summaries

Range Site Description

The potential natural vegetation of these study sites is native shortgrass prairie and is dominated by short grasses with a few midgrasses and a variety of forbs. Almost no shrubs or woody species occur. The most prevalent grasses are blue grama and buffalograss with blue grama being the dominant species. In excellent condition, the short grasses comprise 65 to 80% of the total composition. Midgrasses constitute less than 20% of the total. Western wheatgrass and/or vine mesquite are the more common midgrasses; small amounts of sideoats grama may occur in small amounts on more loamy sites. Other midgrasses such as sand dropseed, tumble windmillgrass, sand muhly, silver bluestem, tabosa grass, gummy lovegrass, and squirreltail can comprise up to 10% of the total composition. Forbs can make up to 5% of the total composition and are moisture dependent and are more abundant in above average rainfall years. The main factors limiting plant growth are the clayey textured subsoils.

Location C1 was sampled, using the double-sampling method, and found to be in good range condition (66.1 percent). The dominant plant species at location C1 were blue gramma, buffalograss, scarlet globemallow, and prairie coneflower. Out of the two locations, C1 had the highest percentage of forbs and cactus. C1 had an average of 17.7 percent forbs and cactus whereas C2 had an average of .4 percent forbs and cactus. The average annual production for C1 was 1339.2 pounds per acre due to the high amount of forbs. C1 had an average of 2,868.6 pounds per acre of litter. The estimated bare ground on C1 was only 6.5 percent.

Location C2 was sampled, using the double-sampling method, and found to be in good range condition (67.2 percent). The dominant plant species at location C2 were buffalograss, blue gramma, and pricklypear cactus. Out of the two locations, C2 had the highest percentage of buffalograss. C2 had an average of 51.3 percent buffalograss, whereas C1 had an average of 14 percent buffalograss. The average annual production for C2 was 510.8 pounds per acre and the average amount of litter was 2,174.8 pounds per acre. The estimated bare ground on C2 was 15 percent.

Table 1. Texas Site Characteristics.

| Variable | C1 Texas , Proper Grazing Use | C2 Texas, Heavy Grazing Use |
|---|---|---|
| Range Site | Clay loam | Clay loam |
| Avg. Annual Precip. (in) | 16 to 21 | 16 to 21 |
| Slope (%) | 3.0 | 2.0 |
| Elevation (ft) | 4000 | 3100 |
| Aspect | South | South |
| Potential Climax Vegetation | Blue grama/buffalograss | Blue grama/buffalograss |
| Range Condition | High Good | Good |
| Dominant Plants | Blue grama<br>Buffalograss<br>Scarlet globemallow<br>Prairie coneflower | Buffalograss<br>Blue grama<br>Pricklypear cactus |
| Primary Use | Cow/calf operation; summer to fall use; rotation is used periodically | Yearlings and cow/calf; summer to fall use; no grazing system |
| Management History | No fertilizer, brush control, or burning | No fertilizer, brush control, or burning |

Table 2. Texas Vegetation Data

| Variable | C1 Texas Proper Grazing Use | C2 Texas Heavy Grazing Use |
|---|---|---|
| Grass Canopy Cover (CC) | 9.83 | 8.95 |
| Forb CC % | 1.12 | 0.00 |
| Shrub/H. Shrub CC % | 0.10 | 0.00 |
| Standing Dead CC% | 11.70 | 1.43 |
| Cacti CC% | 0.37 | 0.03 |
| Basal Vegetation % | 13.84 | 2.99 |
| Cryptogam <1cm ht. CC % | 0.00 | 0.00 |
| Cryptogam >1cm ht. CC % | 0.00 | 0.00 |
| Litter % | 83.16 | 83.67 |
| Bare Soil % | 2.99 | 13.33 |
| Rock % | 0.00 | 0.00 |
| Production (lbs/ac) | 1339.0 | 543.3 |
| Litter (lbs/ac) | 2868.6 | 2174.8 |
| Random Roughness (std dev.) | 10.12 | 7.18 |

# N A R R A T I V E   P E D O N   D E S C R I P T I O N

Pedon: Olton
Soil Survey Number S90-TX-035-001
Location: Bosque County, Texas
Oldham County. Location C1.
Latitude: 35-16-30-N
Physiography: Hillside or mountainside in
Slope: 3% south facing
Precipitation: cm - Moisture Regime.
Water Table Depth:
Drainage: Well drained
Stoniness: Erosion or Deposition: Slight
Parent Material: loess
Classification: Fine, mixed, thermic Aridic Paleustoll
Diagnostic Horizons:
Described By:
Vegetation: buffalo grass, blue grama, and mesquite (Cholla). High plains eolian mantle. Weak 1/8" thick crust.

NSSL Pedon Number: 90P0855
Print Date: 01/13/92

Longitude: 102-16-46-W

Elevation: 1204 m MSL

Permeability: Moderately slow
Land Use:
Runoff:

Sample Date: 7/90

A1 -- 0 to 3 cm; brown to dark brown (7.5YR 4/2) dry loam and dark brown (7.5YR 3/2) moist loam; weak fine platy structure parting to weak fine subangular blocky; slightly hard, friable; many very fine roots; common fine and medium tubular pores; slightly effervescent; clear smooth boundary.
90P5101

A2 -- 3 to 15 cm; brown to dark brown (7.5YR 4/2) dry clay loam and dark brown (7.5YR 3/2) moist clay loam; moderate medium blocky structure; hard, firm; common fine and many very fine roots; common fine tubular pores; slightly effervescent; clear smooth boundary.
90P5102

Bt1 -- 15 to 38 cm; dark reddish brown (5YR 3/3) dry clay loam and dark reddish brown (5YR 3/3) moist clay loam; weak coarse prismatic structure parting to strong medium blocky; very hard, very firm; few very fine and fine roots; few fine tubular pores; few discontinuous faint clay films; slightly effervescent; gradual smooth boundary.
some small dissiration crack
90P5103

Bt2 -- 38 to 69 cm; reddish brown (5YR 5/4) dry clay loam and reddish brown (5YR 4/4) moist clay loam; weak coarse prismatic structure parting to strong medium blocky; very hard, very firm; few very fine and common fine roots; few fine tubular pores; few continuous faint clay films; slightly effervescent; clear smooth boundary.
90P5104

Bt3 -- 69 to 91 cm; yellowish red (5YR 5/6) dry clay loam and yellowish red (5YR 4/6) moist clay loam; weak coarse prismatic structure parting to moderate medium blocky; very hard, very firm; few very fine and common fine roots; common fine tubular pores; few patchy clay films; strongly effervescent; gradual smooth boundary.
common threads and films of CaCO3
90P5105

Bt4 -- 91 to 112 cm; yellowish red (5YR 5/6) dry clay loam and yellowish red (5YR 4/6) moist clay loam; weak coarse prismatic structure parting to moderate medium blocky; very hard, very firm; few fine roots; common fine tubular pores; few patchy clay films; strongly effervescent; abrupt wavy boundary.
common threads and films of CaCO3
90P5106

Btk1 --112 to 145 cm; pink (5YR 8/4) dry clay and reddish yellow (5YR 7/6) moist clay; weak coarse prismatic structure parting to moderate medium blocky; very hard, very firm; few fine roots; common fine tubular pores; violently effervescent; gradual smooth boundary.
50% CaCO3 by volume, soft concretions (7.5YR 3/2) and finely divided krotovina; no pressure faces
90P5107

Btk2 --145 to 160 cm; reddish yellow (5YR 6/6) dry clay and yellowish red (5YR 5/6) moist clay; weak coarse prismatic structure parting to moderate medium blocky; very hard, very firm; few fine roots; common fine tubular pores; violently effervescent.
20% CaCO3 by volume; threads, films, soft concretions
90P5108

# NARRATIVE PEDON DESCRIPTION

Pedon: Olton
Soil Survey Number S90-TX-381-001
Location: Randall County, Texas
Randall County. Location C2.
Latitude: 35-02-30-N
Physiography: Hillside or mountainside in
Slope: 2% south facing
Precipitation: cm - Moisture Regime.
Water Table Depth:
Drainage: Well drained
Stoniness: Erosion or Deposition: Slight
Parent Material: loess
Classification: Fine, mixed, thermic Aridic Paleustoll
Diagnostic Horizons:
Described By:
Vegetation: buffalo grass, blue grama, and mesquite. Weak, thin 1/8" crust.

NSSL Pedon Number: 90P0860
Print Date: 01/13/92

Longitude: 101-47-32-W

Elevation: m MSL

Permeability: Moderately slow
Land Use:
Runoff:

Sample Date: 7/90

A1 -- 0 to 3 cm; brown to dark brown (7.5YR 4/2) dry loam and dark brown (7.5YR 3/2) moist loam; weak fine platy structure parting to moderate medium granular; slightly hard, friable; many fine roots; few fine tubular pores; slightly effervescent; abrupt smooth boundary.
90P5125

A2 -- 3 to 20 cm; brown to dark brown (7.5YR 4/2) dry clay loam and dark brown (7.5YR 3/2) moist clay loam; moderate medium blocky structure; hard, firm; many fine roots; few fine tubular pores; few continuous faint clay films; slightly effervescent; clear smooth boundary.
90P5126

Bt1 -- 20 to 33 cm; brown to dark brown (7.5YR 4/2) dry clay loam and dark brown (7.5YR 3/2) moist clay loam; moderate medium blocky structure; very hard, very firm; common fine roots; few fine tubular pores; few continuous faint clay films; slightly effervescent; gradual smooth boundary.
90P5127

Bt2 -- 33 to 56 cm; brown to dark brown (7.5YR 4/4) dry clay loam and dark brown (7.5YR 3/4) moist clay loam; weak coarse prismatic structure parting to moderate medium blocky; very hard, very firm; few fine and common coarse roots; few fine tubular pores; few continuous faint clay films; slightly effervescent; gradual smooth boundary.
90P5128

Bt3 -- 56 to 84 cm; brown to dark brown (7.5YR 4/4) dry clay loam and yellowish red (5YR 4/6) moist clay loam; weak coarse prismatic structure parting to moderate medium blocky; very hard, very firm; few fine tubular pores; few continuous faint clay films; slightly effervescent; gradual smooth boundary.
few fine thin threads and films of CaCO3
90P5129

Bt4 -- 84 to 117 cm; yellowish red (5YR 4/6) dry clay loam and reddish brown (5YR 4/4) moist clay loam; moderate medium blocky structure; very hard, very firm; few fine tubular pores; strongly effervescent; clear wavy boundary.
few fine thin threads and films of CaCO3 (10% by volume)
90P5130

Btk1 --117 to 140 cm; reddish yellow (5YR 6/6) dry clay loam and yellowish red (5YR 5/6) moist clay loam; weak medium subangular blocky structure; very hard, very firm; few fine tubular pores; violently effervescent.
50% by volume CaCO3 as finely divided soft masses and small soft concretions
90P5131

Btk2 --140 to 152 cm; reddish yellow (5YR 6/6) dry clay loam and yellowish red (5YR 5/6) moist clay loam; weak medium subangular blocky structure; very hard, very firm; few fine tubular pores; violently effervescent.
90P5132

Table 3. Selected soil horizon characteristics of the master soil pedon sampled for site C1, Texas - Olton clay loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragment (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-3 | 26.5 | 52.7 | 20.8 | L | 0.99 | 3.45 | . | 25.8 | 10.6 |
| A2 | 3-15 | 36.6 | 39.1 | 24.3 | CL | 1.45 | 1.59 | . | 19.2 | 10.2 |
| Bt1 | 15-38 | 33.3 | 33.9 | 32.8 | CL | 1.67 | 1.00 | . | 23.5 | 13.7 |
| Bt2 | 38-68 | 30.3 | 37.4 | 32.3 | CL | 1.69 | 0.28 | . | 22.3 | 13.3 |
| Bt3 | 68-92 | 37.1 | 37.8 | 25.1 | CL | 1.56 | 0.18 | . | 21.9 | 11.1 |
| Bt4 | 92-113 | 45.2 | 30.2 | 24.6 | CL | 1.55 | 0.13 | . | 22.9 | 10.8 |
| Btk1 | 113-145 | 21.2 | 41.7 | 37.1 | C | 1.65 | 0.18 | . | 20.7 | 11.7 |
| Btk2 | 145-161 | 19.5 | 46.9 | 33.6 | C | 1.68 | 0.12 | . | 21.0 | 10.7 |

[1]Key to texture; L=Loam, CL=Clay-loam, C=Clay.

Table 4. Selected soil horizon characteristics of the master soil pedon sampled for site C2, Texas - Olton clay loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragment (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-3 | 26.6 | 50.3 | 23.1 | L | 1.31 | 3.04 | . | 21.4 | 10.7 |
| A2 | 3-20 | 42.8 | 34.1 | 23.1 | CL | 1.50 | 1.58 | . | 18.7 | 9.9 |
| Bt1 | 20-33 | 36.9 | 28.2 | 34.9 | CL | 1.67 | 1.07 | . | 23.7 | 14.5 |
| Bt2 | 33-56 | 30.6 | 33.5 | 35.9 | CL | 1.69 | 0.66 | . | 23.8 | 14.5 |
| Bt3 | 56-84 | 27.7 | 35.9 | 36.4 | CL | 1.77 | 0.29 | 1 | 23.8 | 15.1 |
| Bt4 | 84-117 | 29.6 | 38.6 | 31.8 | CL | 1.61 | 0.19 | Tr | 24.7 | 14.1 |
| Btk1 | 117-140 | 26.1 | 35.2 | 38.7 | CL | 1.58 | 0.20 | 8 | 22.3 | 11.7 |
| Btk2 | 140-150 | 22.6 | 38.2 | 39.2 | CL | 1.59 | 0.18 | 3 | 22.0 | 11.8 |

[1]Key to texture; L=Loam, CL=Clay-loam.

Table 5. Average soil bulk density measured at 2 depths by the complience cavity method before rainfall simulation began and 24 hours after the very wet rainfall simulation ended for sites C1 and C2 in Texas.

| Site | Sampled | Depth (cm) | Bulk Density ($g/cm^3$) | Sample Size |
|---|---|---|---|---|
| C1 | Before Dry | 0.0-2.5 | 0.76 | 6 |
| | | 2.5-10.0 | 1.23 | 6 |
| | After Very Wet | 0.0-2.5 | 0.71 | 6 |
| | | 2.5-10.0 | 1.35 | 6 |
| C2 | Before Dry | 0.0-2.5 | 1.08 | 6 |
| | | 2.5-10.0 | 1.39 | 6 |
| | After Very Wet | 0.0-2.5 | 0.94 | 6 |
| | | 2.5-10.0 | 1.24 | 6 |

Table 6. Average root biomass measured at 2 depths for sites C1 and C2 in Texas.

| Site | Landscape Position | Depth (cm) | Root Biomass (kg/ha) | Sample Size |
|---|---|---|---|---|
| C1 | Basal | 0.0-2.5 | 1420.49 | 6 |
| | | 2.5-10.0 | 184.00 | 6 |
| C2 | Basal | 0.0-2.5 | 1208.36 | 6 |
| | | 2.5-10.0 | 218.22 | 6 |

Table 7. Average hydrologic characteristics of dry and wet antecedent moisture condition rainfall simulation runs for sites C1 and C2 in Texas.

| Site | Cumulative Runoff (mm) | Cumulative Infiltration (mm) | Cumulative Sediment Yield (kg/ha) | Runoff Rate (mm/hr) | Infiltration Rate (mm/hr) | Sediment Yield Rate (kg/ha/hr) |
|---|---|---|---|---|---|---|
| At 60 Minutes During Dry Runs | | | | | | |
| C1 | 6.23 | 49.76 | 67.99 | 10.44 | 47.81 | 76.05 |
| C2 | 21.31 | 30.17 | 207.77 | 40.76 | 10.61 | 168.59 |
| At 30 Minutes During Wet Runs | | | | | | |
| C1 | 3.08 | 24.36 | 35.54 | 17.71 | 35.41 | 140.29 |
| C2 | 9.56 | 15.33 | 63.84 | 35.04 | 11.37 | 192.53 |

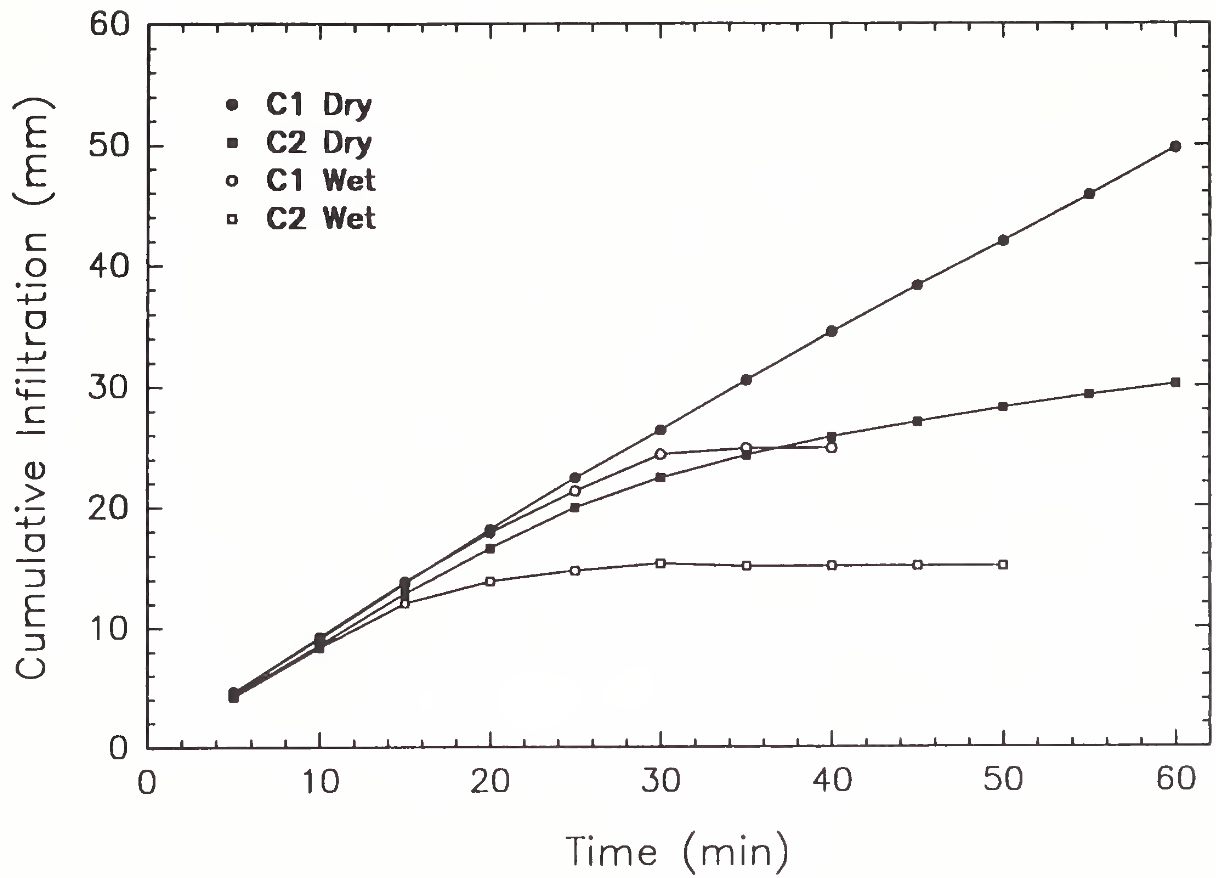


Figure 1. Cumulative infiltration for sites C1 and C2 in Texas.

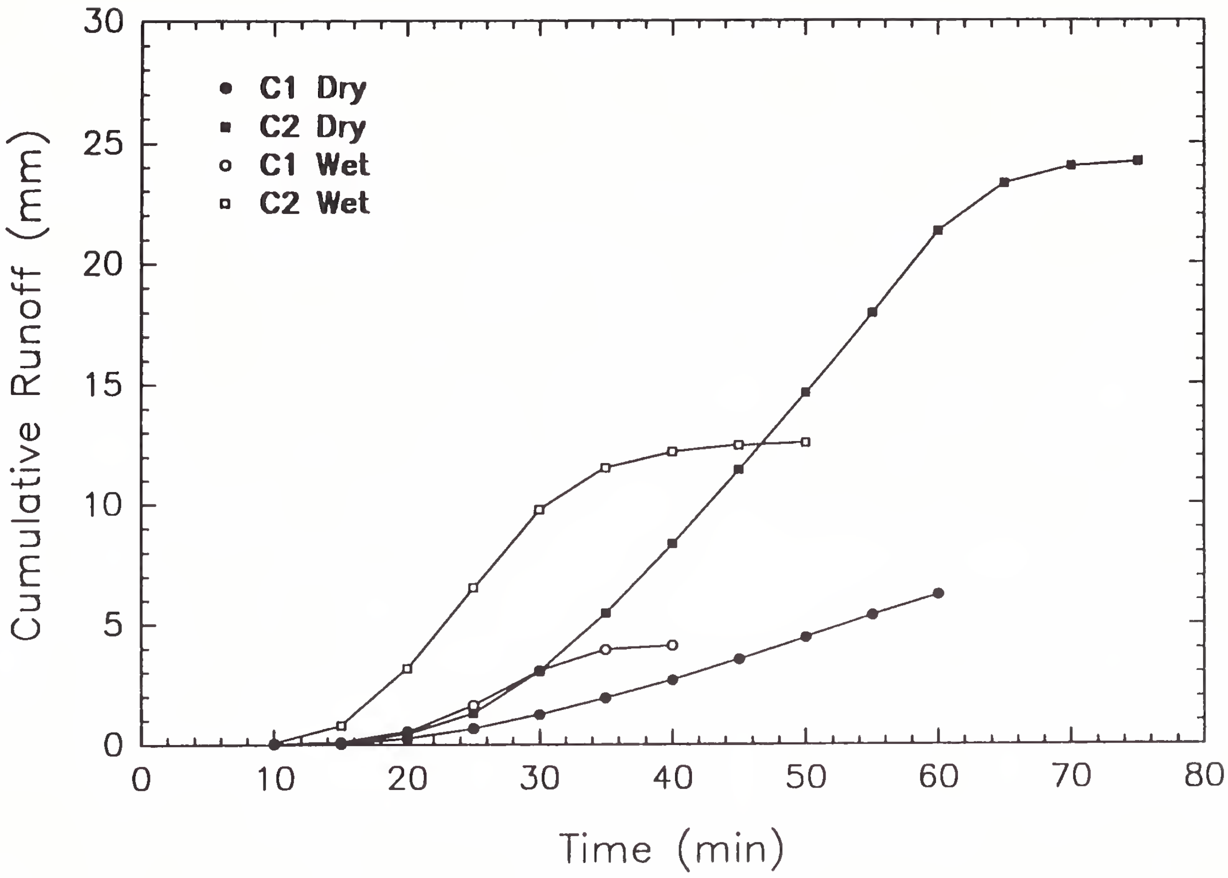


Figure 2. Cumulative runoff for sites C1 and C2 in Texas.

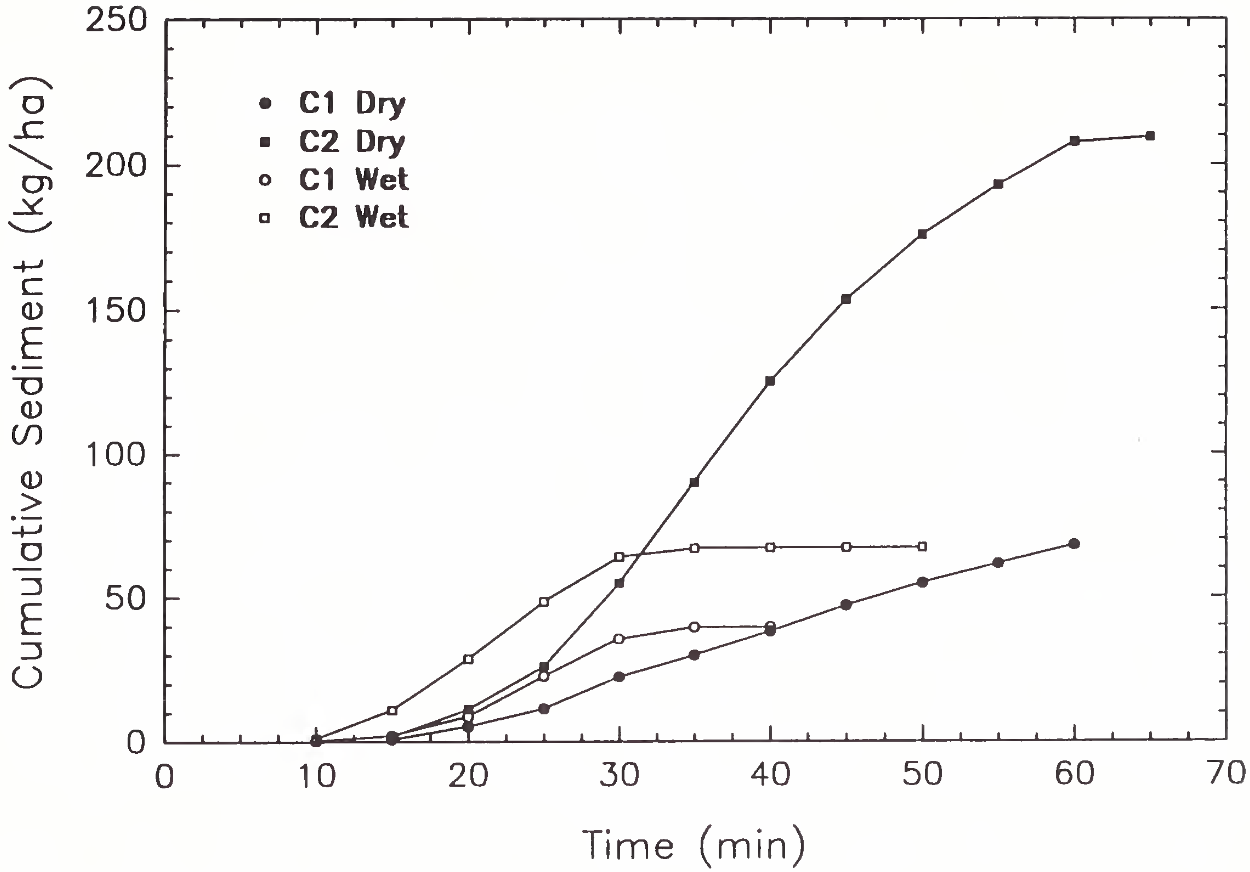


Figure 3. Cumulative sediment yield for sites C1 and C2 in Texas.

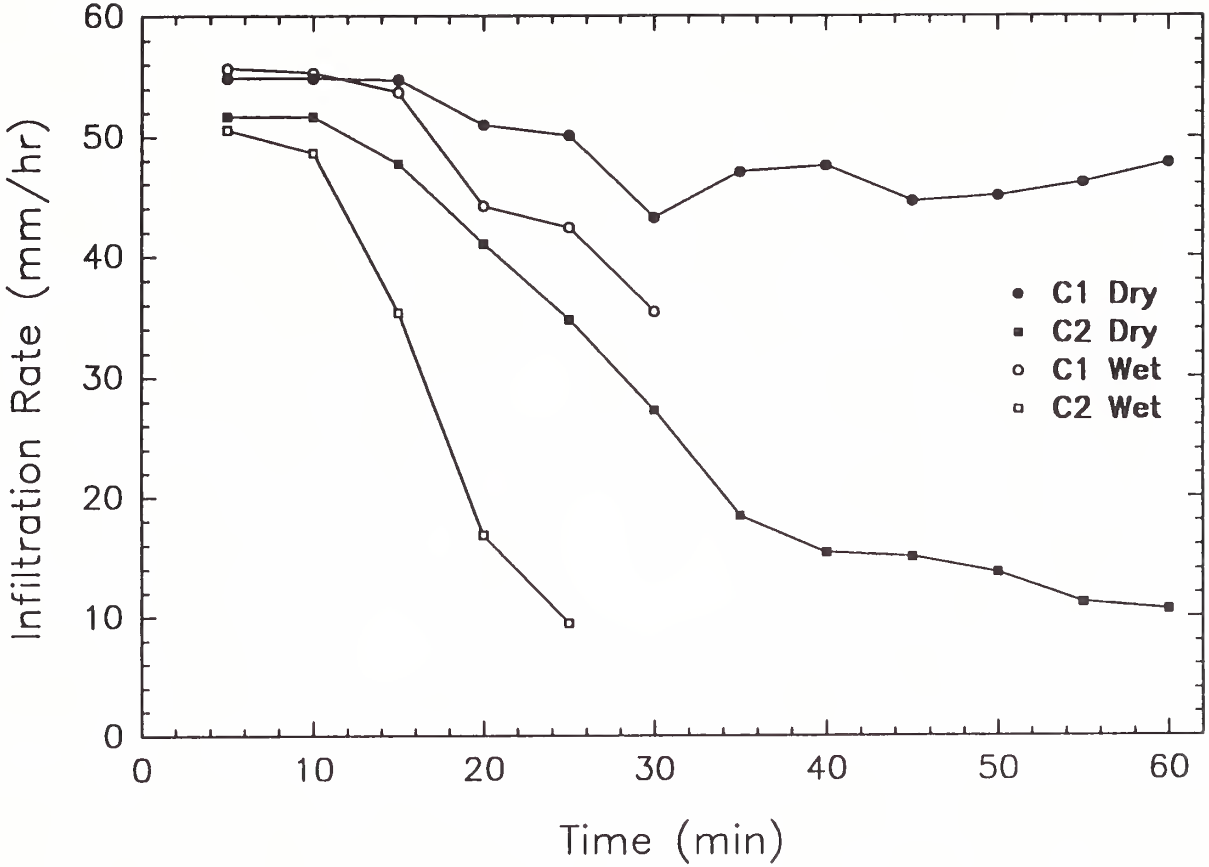


**Figure 4. Instantaneous infiltration rate for sites C1 and C2 in Texas.**

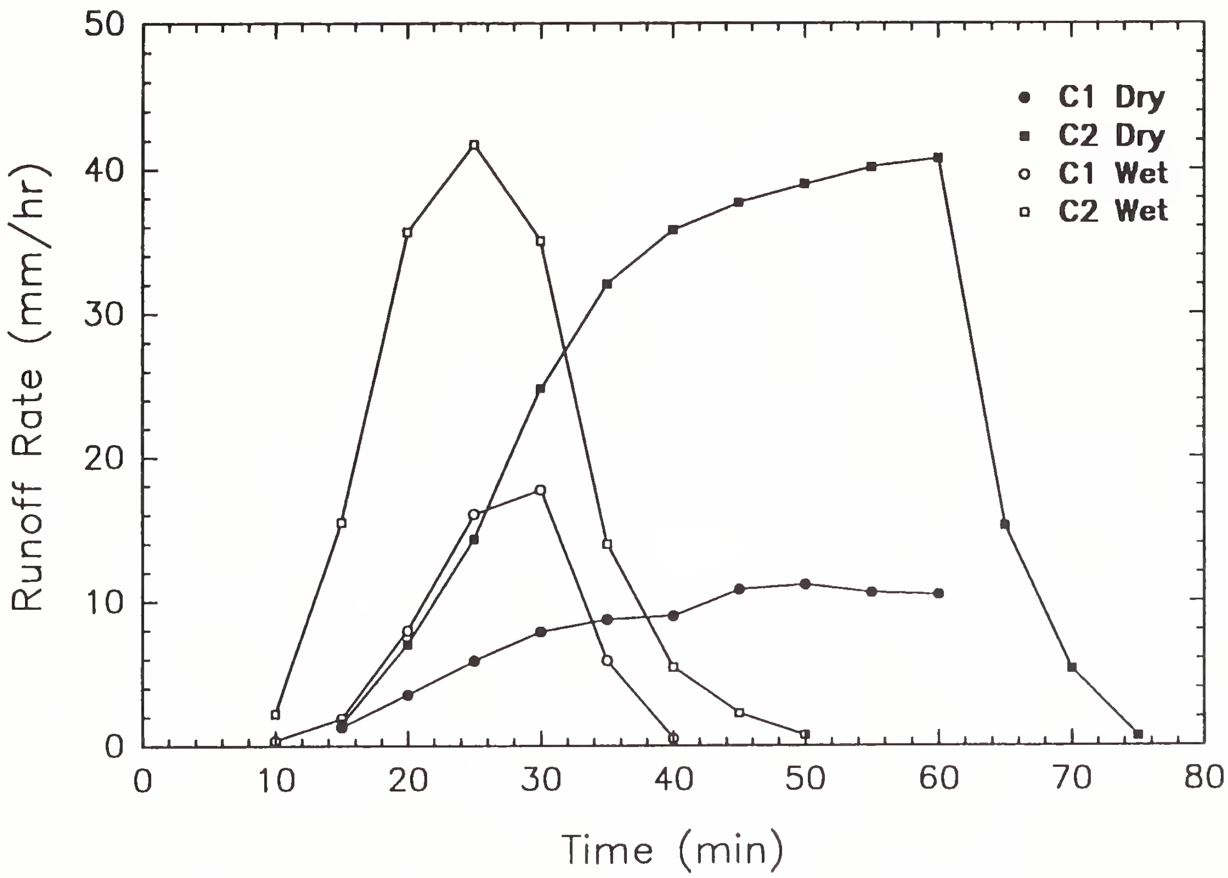


Figure 5. Instantaneous runoff rate for sites C1 and C2 in Texas.

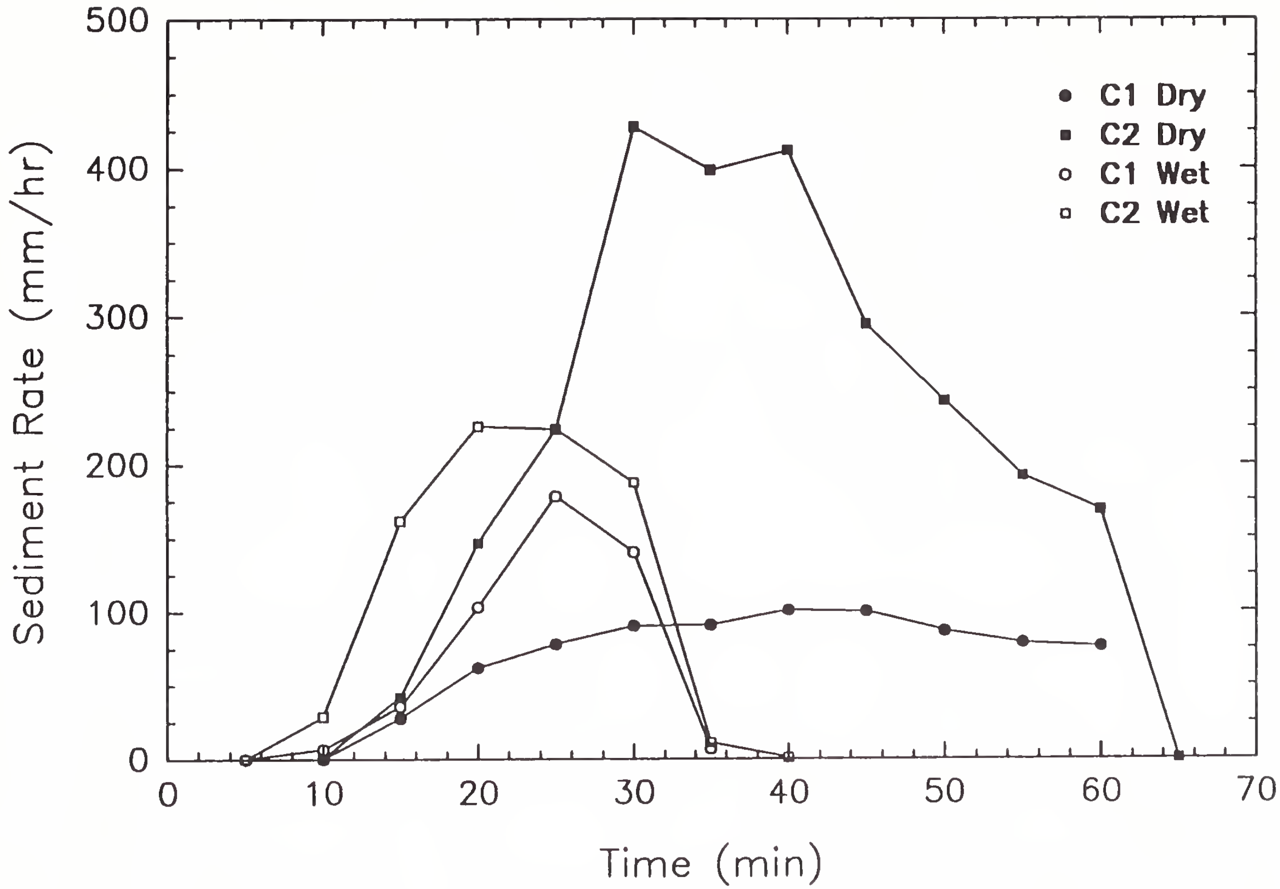


Figure 6. Instantaneous sediment yield rate for sites C1 and C2 in Texas.

# KANSAS Data Summaries

Range Site Description

The potential natural vegetation of this sites is a tall grass prairie. Big bluestem, little bluestem, indiangrass, switchgrass, and eastern gama grass produce about 85% of the total vegetation. Subdominate grasses include blue grama, buffalograss, Canada wildrye, prairie junegrass, sideoats grama, tall dropseed, and sedges. This site is diverse with respect to forbs. Common forbs include pitcher sage, heath aster, yarrow, western ragweed, Missouri goldenrod, wooly verbena, pussytoes, ironweed, and stiff sunflower. Ceanothus and leadplant are common woody species. As this site deteriorates, common invaders are common ragweed, Japanese brome, Kentucky bluegrass, buckbrush, prairie threeawn, smooth sumac, red cedar, and osageorange.

On an evolutionary scale, the vegetation on this site developed under the influence of fire and large ungulates such as bison, elk, and deer. When maintained in good to excellent condition, this site provides excellent spring and summer forage for cattle. Crude protein levels drop as tall grass species become mature and set seed. This site provides excellent nesting areas for prairie chickens and forage for whitetail deer and quail. Numerous rodents and other small animals utilize this site because of adequate cover of the tall grasses.

Location E1 was sampled, using the double-sampling method, and found to be in poor condition (14.3 percent). This location had been overgrazed and was dominated by annual broomweed (22.2%), western ragweed (8.5%), missouri goldenrod (6.0%), and sand dropseed (8.4%). E1 had only 0.4 percent bluestems (big and little) and 0.1 percent indiangrass as compared to E2 which had 65.3 percent bluestems and 15.1 percent indiangrass. Compared to E3, E1 had only traces of sideoats and buffalograss whereas E3 had 27.5 percent sideoats grama and 25 percent buffalograss. The average annual production for E1 1,727.5 pounds per acre. In comparison, if E1 was in excellent condition under a normal year, it could produce above 3,500 pounds per acre. There was an average of 1,815.7 pounds per acre of litter on E1. The estimated bare ground on E1 was 31.6 percent and the amount of cryptograms was a minimum.

Location E2 was sampled, using the double-sampling method, and found to be in good condition (72.8 percent). This location was prescribed burned in mid April 1991. Out of the three locations, E2 had the highest percentage of bluestem grasses (big and little) and indiangrass. E2 had 65.3 percent bluestems whereas E1 had only .4 percent bluestems and F3 had 24.5 percent bluestems. E2 also had 15 percent indiangrass whereas E1 had 0.1 percent indiangrass and E3 had only 0.6 percent indiangrass. The average annual production for E2 was 2,063.5 pounds per acre. In comparison, if E2 was in excellent condition under a normal year, it could produce about 3,500 pounds per acre. There was an average of 1,310.1 pounds per acre of litter on E2. The estimated bare ground on E2 was 21.6 percent and the amount of cryptogram was minimum.

Location E3 was sampled, using the double-sampling method, and found to be in fair condition (36 percent). This location was burned by a wild fire during the latter part of March 1991. Out of the three locations, E3 had the highest percentage of sideoats grama and buffalograss. E3 had 27.5 percent sideoats whereas E1 had only traces and E2 had only 0.7 percent sideoats. E3 also had 25 percent buffalograss whereas E1 and E2 had only

traces of buffalograss. The average annual production for E3 was 508 pounds per acre. In comparison, if E3 was in excellent condition under a normal year, it could produce above 3,500 pounds per acre. There was an average of 380.4 pounds per acre of litter on E3. The estimated bare ground on the E3 was 57.5 percent and the amount of cryptograms was minimum.

Table 1. Kansas Site Characteristics.

| Variable | E1 Kansas Heavy Grazing Use | E2 Kansas None or Light Grazing Use | E3 Kansas Heavy Grazing Use |
|---|---|---|---|
| Range Site | Loamy Upland | Loamy Upland | Loamy Upland |
| Avg. Annual Precip. (in) | 34 | 34 | 34 |
| Slope (%) | 5.0 | 5.0 | 3.0 |
| Elevation (ft) | 1100 | 1100 | 1500 |
| Aspect | West | East | South |
| Potential Climax Vegetation | Big bluestem/little bluestem | Big bluestem/little bluestem | Big bluestem/little bluestem |
| Range Condition | Poor | High Good | Fair |
| Dominant Plants | Annual broomweed<br>Western ragweed<br>Sand dropseed<br>Prairie coneflower | Little bluestem<br>Big bluestem<br>Indiangrass<br>Tall dropseed | Sideoats grama<br>Buffalograss<br>Little bluestem<br>Big bluestem |
| Primary Use | Cow/calf operation; continuous grazing | Cow/calf operation; summer use | Cow/calfoperation; summer use |
| Management History | No fertilizer, brush control within past year, no burning | No fertilizer, no brush control, occasionally burned | No fertilizer, no brush control, occasionally burning |

Table 2. Kansas Vegetation and Plot Data.

| Variable | E1 Kansas Heavy Grazing Use | E2 Kansas None or Light Grazing Use | E3 Kansas Heavy Grazing Use |
|---|---|---|---|
| Grass Canopy Cover (CC) | 21.77 | 52.21 | 32.24 |
| Forb CC % | 32.65 | 6.67 | 5.00 |
| Shrub/H. Shrub CC % | 0.00 | 0.00 | 0.00 |
| Standing Dead CC% | 0.99 | 2.01 | 0.92 |
| Cacti CC% | 0.00 | 0.00 | 0.00 |
| Basal Vegetation % | 2.04 | 2.07 | 2.96 |
| Cryptogam <1cm ht. CC % | 0.00 | 0.03 | 0.00 |
| Cryptogam >1cm ht. CC % | 0.00 | 0.00 | 0.00 |
| Litter % | 70.54 | 74.29 | 55.24 |
| Bare Soil % | 27.42 | 23.61 | 41.80 |
| Rock % | 0.00 | 0.00 | 0.00 |
| Production (lbs/ac) | 1727.50 | 2063.50 | 508.00 |
| Litter (lbs/ac) | 1815.70 | 764.42 | 380.35 |
| Random Roughness (std dev.) | 11.63 | 9.19 | 8.83 |

## NARRATIVE PEDON DESCRIPTION

Pedon: Martin
Soil Survey Number S91-KS-073-003
Location: Greenwood County, Kansas
Map 78, Sec. 34, T. 27 S., R. 11 E.; Ray Moe Coble (dairy).
Latitude: - - -N
Geomorphic Position:
Microrelief: linear
Slope: 6% west facing
Precipitation: cm - Moisture Regime.
Water Table Depth:
Drainage: Moderately well drained
Stoniness: Erosion or Deposition: Moderate
Parent Material: residuum from shale material
Classification: Fine, montmorillonitic, mesic Vertic Argiudoll
Diagnostic Horizons:
Described By: C. Watts, C. Franks, D. Owens, P. Finnell
Vegetation: weeds, brome; cracks are on prism faces to 59 cm.

NSSL Pedon Number: 91P0846
Print Date: 08/19/92

Longitude: - - -W

Elevation: 330 m MSL

Permeability: Slow
Land Use:
Runoff:

Sample Date: 6/91

A -- 0 to 20 cm; very dark gray (10YR 3/1) and dark gray (10YR 4/1) crushed moist silty clay loam; moderate medium granular structure; slightly hard, friable, slightly sticky, slightly plastic; many fine roots; clear wavy boundary.
91P5129

BA -- 20 to 36 cm; very dark gray (10YR 3/1) and very dark gray (10YR 3/1) crushed moist silty clay loam; moderate medium subangular blocky structure parting to moderate medium granular; slightly hard, friable, sticky, plastic; common fine and common very fine roots; slightly effervescent; clear smooth boundary.
91P5130

Bt -- 36 to 58 cm; very dark gray (10YR 3/1) and very dark grayish brown (10YR 3/2) crushed moist silty clay loam; common distinct mottles; strong medium subangular blocky structure; slightly hard, friable, sticky, plastic; few fine and common very fine roots; continuous pressure faces on faces of peds; slightly effervescent; abrupt smooth boundary.
91P5131

Bss1 -- 58 to 97 cm; brown to dark brown (10YR 4/3) and yellowish brown (10YR 5/4) crushed moist silty clay; common medium distinct mottles; weak fine prismatic structure parting to moderate medium subangular blocky; hard, firm, very sticky, very plastic; common very fine roots; many pressure faces and organic coats; few iron-manganese concretions; slightly effervescent; clear smooth boundary.
91P5132

Bss2 -- 97 to 137 cm; brown (10YR 5/3) and brownish yellow (10YR 6/6) crushed moist silty clay; common medium distinct mottles; moderate medium subangular blocky structure; very hard, very firm, very sticky, very plastic; few very fine roots; few pressure faces and organic coats; few iron-manganese concretions; slightly effervescent; abrupt smooth boundary.
91P5133

C --137 to 160 cm; yellowish brown (10YR 5/6) and olive gray (5Y 5/2) moist silty clay; massive; very hard, very firm, very sticky, very plastic; few very fine roots; abrupt smooth boundary.
91P5134

R --160 to 0 cm;.
hard limestone bedrock

# NARRATIVE PEDON DESCRIPTION

Pedon: Martin
Soil Survey Number S91-KS-073-001
Location: Greenwood County, Kansas
Map 47, Sec. 22, T. 25 S.; Latitude: 96 degrees 23' 47", Longitude: 37 degrees 51' 53"; Greenwood Co., Kansas
Latitude: - - -N
Geomorphic Position:
Microrelief: linear
Slope: 6% east facing
Precipitation: cm - Moisture Regime.
Water Table Depth:
Drainage: Moderately well drained
Stoniness: Erosion or Deposition: Slight
Parent Material: residuum from shale material
Classification: Fine, montmorillonitic, mesic Vertic Argiudoll
Diagnostic Horizons:
Described By: C. Watts, P. Fennell, C. Franks
Vegetation: little bluestem.

NSSL Pedon Number: 91P0836
Print Date: 08/19/92
Longitude: - - -W
Elevation: 344 m MSL
Permeability: Slow
Land Use:
Runoff:
Sample Date: 6/91

A1 -- 0 to 20 cm; very dark gray (10YR 3/1) crushed moist silty clay loam; moderate medium granular structure; slightly hard, friable, sticky, plastic; few medium roots throughout and many fine roots throughout; slightly effervescent; clear smooth boundary.
91P5075

A2 -- 20 to 33 cm; very dark gray (10YR 3/1) crushed moist silty clay loam; moderate medium subangular blocky structure parting to moderate fine subangular blocky; slightly hard, friable, sticky, plastic; many fine roots throughout; slightly effervescent; clear smooth boundary.
91P5076

BA -- 33 to 46 cm; very dark grayish brown (2.5Y 3/2) crushed moist silty clay loam; moderate medium subangular blocky structure parting to fine subangular blocky; slightly hard, friable, sticky, plastic; common fine roots throughout; many very fine vesicular pores; pressure faces; slightly effervescent; clear smooth boundary.
91P5077

Bt1 -- 46 to 58 cm; very dark grayish brown (2.5Y 3/2) crushed moist silty clay; moderate medium subangular blocky structure; hard, firm, very sticky, very plastic; common fine roots throughout and many very fine roots throughout; continuous faint pressure faces on vertical and horizontal faces of peds; few iron-manganese concretions; slightly effervescent; 1 percent pebbles; clear smooth boundary.
91P5078

Bt2 -- 58 to 76 cm; brown to dark brown (7.5YR 4/4) moist silty clay; few fine prominent mottles; moderate medium subangular blocky structure; hard, firm, very sticky, very plastic; common fine roots throughout and common medium roots throughout; continuous prominent pressure faces on vertical and horizontal faces of peds; few iron-manganese concretions; slightly effervescent; 1 percent pebbles; clear smooth boundary.
91P5079

Bss1 -- 76 to 102 cm; olive brown (2.5Y 4/4) crushed moist clay; many fine prominent mottles; moderate medium subangular blocky structure parting to moderate coarse subangular blocky; very hard, very firm, very sticky, very plastic; common fine roots throughout; many continuous prominent pressure faces on vertical and horizontal faces of peds; few iron-manganese concretions; slightly effervescent; clear smooth boundary.
91P5080

Bssk --102 to 122 cm; olive brown (2.5Y 4/4) crushed moist clay; common medium distinct mottles; medium and coarse prismatic structure parting to moderate medium subangular blocky; very hard, very firm, very sticky, very plastic; common fine roots throughout; few carbonate concretions and common iron-manganese concretions; slightly effervescent; abrupt smooth boundary.
91P5081

Bss --122 to 140 cm; olive brown (2.5Y 4/4) crushed moist clay; common medium distinct mottles; medium and coarse prismatic structure parting to moderate medium subangular blocky; very hard, very firm, very sticky, very plastic; few very fine roots throughout; common iron-manganese concretions; slightly effervescent; abrupt smooth boundary.
no organic stains
91P5082

# NARRATIVE PEDON DESCRIPTION

Pedon: Martin
Soil Survey Number S91-KS-073-002
Location: Greenwood County, Kansas
Map 46, Sec. 24, T. 25 S., R. 8 E.; Latitude: 96 degrees 27' 58";
Longitude: 37 degrees 51' 27"; Hap Jackson
Latitude: - - -N
Geomorphic Position:
Microrelief: linear
Slope: 6% south facing
Precipitation: cm - Moisture Regime.
Water Table Depth:
Drainage: Moderately well drained
Stoniness: Erosion or Deposition: Slight
Parent Material: residuum from shale material
Classification: Fine, montmorillonitic, mesic Typic Pelludert
Diagnostic Horizons:
Described By: C. Franks, P. Finnell, J. Warner

NSSL Pedon Number: 91P0841
Print Date: 08/19/92

Longitude: - - -W

Elevation: 442 m MSL

Permeability: Very slow
Land Use:
Runoff:

Sample Date: 6/91

Vegetation: weeds and little bluestem (nonweed); common cracks radiating to surface and material filling cracks to 137 cm; sampling describes a micro high.

A1 -- 0 to 10 cm; very dark gary (2.5Y 3/0) moist silty clay loam; strong medium granular structure; slightly hard, friable, sticky, plastic; few medium and common very fine and fine roots; slightly effervescent; clear smooth boundary.
91P5103

A2 -- 10 to 28 cm; very dark gary (2.5Y 3/0) moist silty clay; weak medium subangular blocky structure parting to strong medium granular; hard, firm, very sticky, very plastic; common very fine and fine roots; slightly effervescent; clear wavy boundary.
91P5104

Bt -- 28 to 48 cm; dark grayish brown (2.5Y 4/2) moist silty clay; weak medium prismatic structure parting to moderate medium subangular blocky; very hard, very firm, very sticky, very plastic; few fine to coarse roots; intersecting slickensides on vertical and horizontal faces of peds; slightly effervescent; gradual wavy boundary.
91P5105

Bss1 -- 48 to 76 cm; brown (10YR 5/3) moist clay; weak medium prismatic structure parting to moderate medium angular blocky; very hard, very firm, very sticky, very plastic; few very fine roots; intersecting slickensides; slightly effervescent; gradual wavy boundary.
915106

Bss2 -- 76 to 119 cm; grayish brown (2.5Y 5/2) moist clay; weak coarse angular blocky structure parting to coarse wedge; extremely hard, extremely firm, very sticky, very plastic; few very fine roots; intersecting slickensides; common soft masses of lime; slightly effervescent; gradual smooth boundary.
91P5107

Bss3 --119 to 137 cm; light yellowish brown (2.5Y 6/4) moist clay; weak coarse subangular blocky structure; extremely hard, extremely firm, very sticky, very plastic; few very fine roots; intersecting slickensides; slightly effervescent; abrupt smooth boundary.
91P5108

C --137 to 147 cm; light gray to gray (5Y 6/1) moist silty clay; very hard, very firm, very sticky, very plastic; slightly effervescent; clear smooth boundary.
there is a one cm wide seam of limestone at the top of the C horizon; intersecting slickensides at C contact
91P5109

Cr --147 to 201 cm; grayish brown (2.5Y 5/2) moist clay; very hard, very firm, very sticky, very plastic; strongly effervescent.
highly fractured shale
91P5110

Table 3. Selected soil horizon characteristics of the master soil pedon sampled for site E1, Kansas - Martin silty clay loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragments (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-21 | 4.8 | 50.9 | 44.3 | SICL | 1.60 | 4.23 | . | 36.1 | 22.1 |
| BA | 21-36 | 5.5 | 47.8 | 46.7 | SICL | 1.87 | 2.17 | Tr | 32.8 | 20.5 |
| Bt | 36-59 | 5.2 | 46.9 | 47.9 | SICL | 1.74 | 1.40 | . | 32.1 | 21.5 |
| Bss1 | 59-97 | 7.5 | 43.8 | 48.7 | SIC | 1.82 | 0.57 | 15 | 28.8 | 20.4 |
| Bss2 | 97-137 | 6.1 | 44.3 | 49.6 | SIC | 1.79 | 0.33 | 10 | 30.6 | 20.2 |
| C | 137-160 | 7.5 | 48.3 | 44.2 | SIC | . | 0.24 | 6 | . | 17.4 |

[1]Key to texture; SICL=Silty clay-loam, SIC=Silty clay.

Table 4. Selected soil horizon characteristics of the master soil pedon sampled for site E2, Kansas - Martin silty clay loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragments (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-20 | 11.1 | 48.3 | 40.6 | SICL | 1.35 | 4.36 | . | 23.8 | 20.2 |
| A2 | 20-33 | 9.2 | 45.8 | 45.0 | SICL | 1.63 | 2.65 | . | 23.7 | 21.3 |
| BA | 33-45 | 7.1 | 40.8 | 52.1 | SICL | 1.73 | 1.81 | . | 26.6 | 19.8 |
| Bt1 | 45-58 | 8.3 | 41.1 | 50.6 | SIL | 1.75 | 1.29 | Tr | 28.3 | 20.6 |
| Bt2 | 58-77 | 6.7 | 40.4 | 52.9 | SIL | 1.87 | 0.90 | Tr | 27.1 | 20.4 |
| Bss1 | 77-101 | 6.7 | 38.9 | 54.4 | C | 1.89 | 0.48 | Tr | 26.6 | 21.1 |
| Bssk | 101-122 | 8.4 | 36.8 | 54.8 | C | 1.85 | 0.31 | 3 | 26.1 | 19.8 |
| Bss | 122-140 | 11.8 | 36.2 | 52.0 | C | 1.83 | 0.33 | 7 | 26.0 | 18.3 |
| C1 | 140-154 | 23.2 | 35.7 | 41.1 | C | . | 0.41 | 8 | . | 15.4 |
| C2 | 154-180 | 18.4 | 48.2 | 33.4 | C | . | 0.14 | . | . | 15.2 |

[1]Key to texture; SICL=Silty clay-loam, SIC=Silty clay, C=Clay.

Table 5. Selected soil horizon characteristics of the master soil pedon sampled for site E3, Kansas - Martin silty clay loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragments (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0-10 | 2.7 | 53.9 | 43.4 | SICL | 1.42 | 4.34 | . | 21.3 | 23.6 |
| A2 | 10-28 | 2.4 | 48.1 | 49.5 | SIC | 1.67 | 2.65 | . | 20.9 | 24.9 |
| Bt | 28-47 | 3.5 | 42.6 | 53.9 | SIC | 1.76 | 1.65 | . | 34.4 | 24.1 |
| Bss1 | 47-77 | 1.8 | 42.1 | 56.1 | C | 1.93 | 0.98 | 2 | 31.4 | 24.2 |
| Bss2 | 77-119 | 4.1 | 40.4 | 55.5 | C | 1.95 | 0.38 | 3 | 36.5 | 22.4 |
| Bss3 | 119-137 | 4.8 | 43.0 | 52.2 | C | 1.89 | 0.22 | Tr | 25.2 | 19.8 |
| C | 137-147 | 3.3 | 48.3 | 48.4 | SIC | . | 0.12 | 3 | . | 19.8 |
| CR | 147-200 | 7.9 | 51.6 | 40.5 | C | 1.85 | 0.10 | . | 22.3 | 17.3 |

[1]Key to texture; SICL=Silty clay-loam, SIC=Silty clay, C=Clay.

Table 6. Average soil bulk density measured at 2 depths by the complience cavity method before rainfall simulation began and 24 hours after the very wet rainfall simulation ended for sites E1, E2, and E3 in Kansas.

| Site | Sampled | Depth (cm) | Bulk Density ($g/cm^3$) | Sample Size |
|---|---|---|---|---|
| E1 | Before Dry | 0.0-2.5 | 0.88 | 6 |
| | | 2.5-10.0 | 1.19 | 6 |
| | After Very Wet | 0.0-2.5 | 0.85 | 5 |
| | | 2.5-10.0 | 1.04 | 6 |
| E2 | Before Dry | 0.0-2.5 | 0.80 | 6 |
| | | 2.5-10.0 | 1.13 | 5 |
| | After Very Wet | 0.0-2.5 | 0.88 | 4 |
| | | 2.5-10.0 | 1.13 | 6 |
| E3 | Before Dry | 0.0-2.5 | 0.79 | 6 |
| | | 2.5-10.0 | 1.09 | 6 |
| | After Very Wet | 0.0-2.5 | 0.95 | 5 |
| | | 2.5-10.0 | 1.06 | 6 |

Table 7. Average depth to the wetting front measured at specified times before and after rainfall simulation runs for sites E1, E2, and E3 in Kansas.

| Site | When Sampled | Depth to Wetting Front (cm) | Sample Size |
|---|---|---|---|
| E1 | 30 m Before Wet Run | 52.7 | 6 |
| | After Wet Run | 70.3 | 6 |
| | 30 m After Very Wet Run | 70.2 | 6 |
| E2 | 30 m Before Wet Run | 54.5 | 6 |
| | After Wet Run | 65.5 | 6 |
| | 30 m After Very Wet Run | 73.0 | 6 |
| E3 | 30 m Before Wet Run | 32.2 | 6 |
| | After Wet Run | 38.0 | 5 |
| | 30 m After Very Wet Run | 40.8 | 6 |

Table 8. Average root biomass measured at 2 depths for sites E1, E2, and E3 in Kansas.

| Site | Landscape Position | Depth (cm) | Root Biomass (kg/ha) | Sample Size |
|---|---|---|---|---|
| E1 | Basal | 0.0-2.5 | 921.80 | 6 |
| | | 2.5-10.0 | 145.28 | 6 |
| E2 | Basal | 0.0-2.5 | 2022.23 | 6 |
| | | 2.5-10.0 | 442.52 | 6 |
| E3 | Basal | 0.0-2.5 | 1356.39 | 6 |
| | | 2.5-10.0 | 413.20 | 6 |

Table 9. Average hydrologic characteristics of dry and wet antecedent moisture condition rainfall simulation runs for sites E1, E2, and E3 in Kansas.

| Site | Cumulative Runoff (mm) | Cumulative Infiltration (mm) | Cumulative Sediment Yield (kg/ha) | Runoff Rate (mm/hr) | Infiltration Rate (mm/hr) | Sediment Yield Rate (kg/ha/hr) |
|---|---|---|---|---|---|---|
| At 60 Minutes During Dry Runs | | | | | | |
| E1 | 0.42 | 56.63 | 2.59 | 1.22 | 55.83 | 5.95 |
| E2 | 0.18 | 53.18 | 1.36 | 0.09 | 53.26 | 0.25 |
| E3 | 3.52 | 53.78 | 29.47 | 7.95 | 49.35 | 79.61 |
| At 30 Minutes During Wet Runs | | | | | | |
| E1 | 0.46 | 27.15 | 3.42 | 1.55 | 53.66 | 9.59 |
| E2 | 0.00 | 26.50 | 0.00 | 0.00 | 52.99 | 0.00 |
| E3* | 8.30 | 16.39 | 80.17 | 25.61 | 32.05 | 203.52 |

* Values reported are averages over 30 minutes or until rainfall ended if run time was less than 30 minutes.

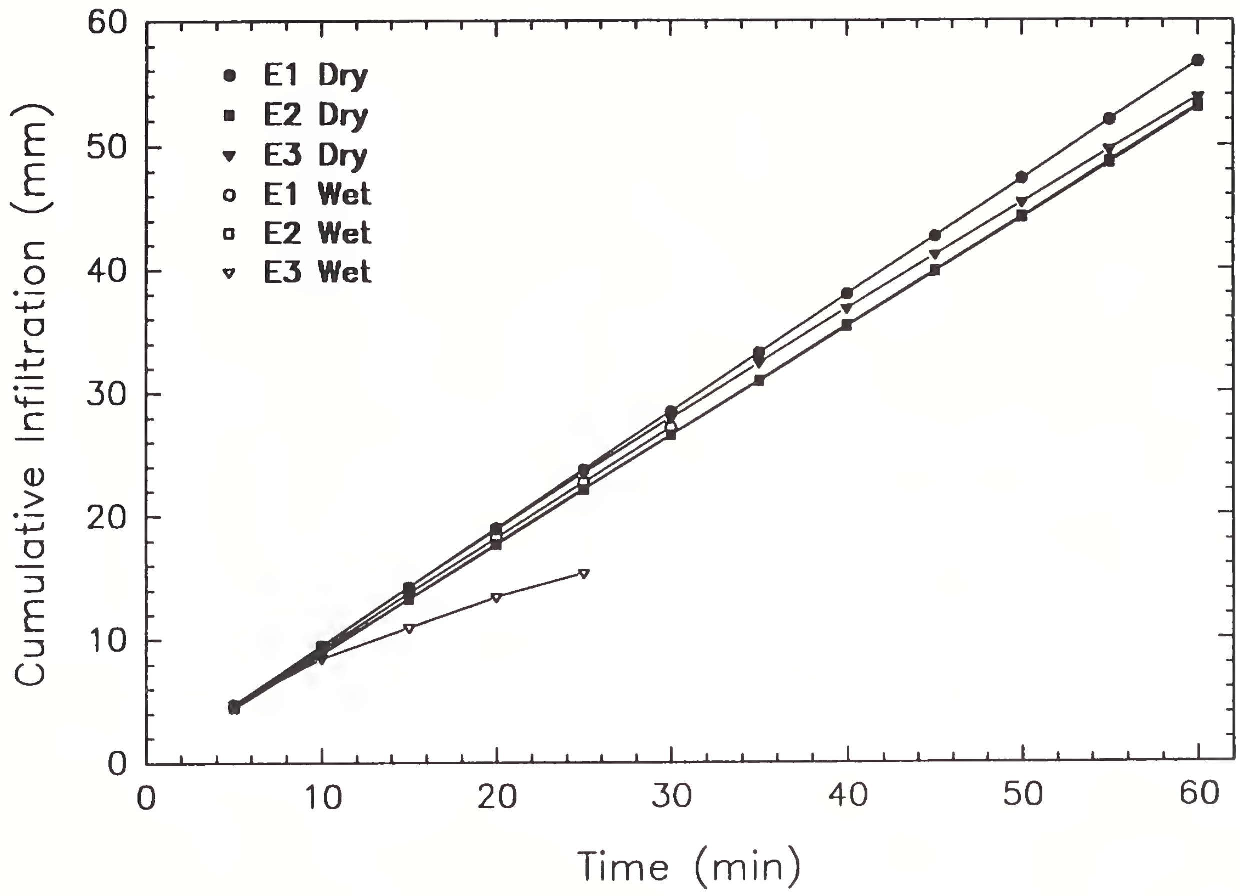


Figure 1. Cumulative infiltration for sites E1, E2, and E3 in Kansas.

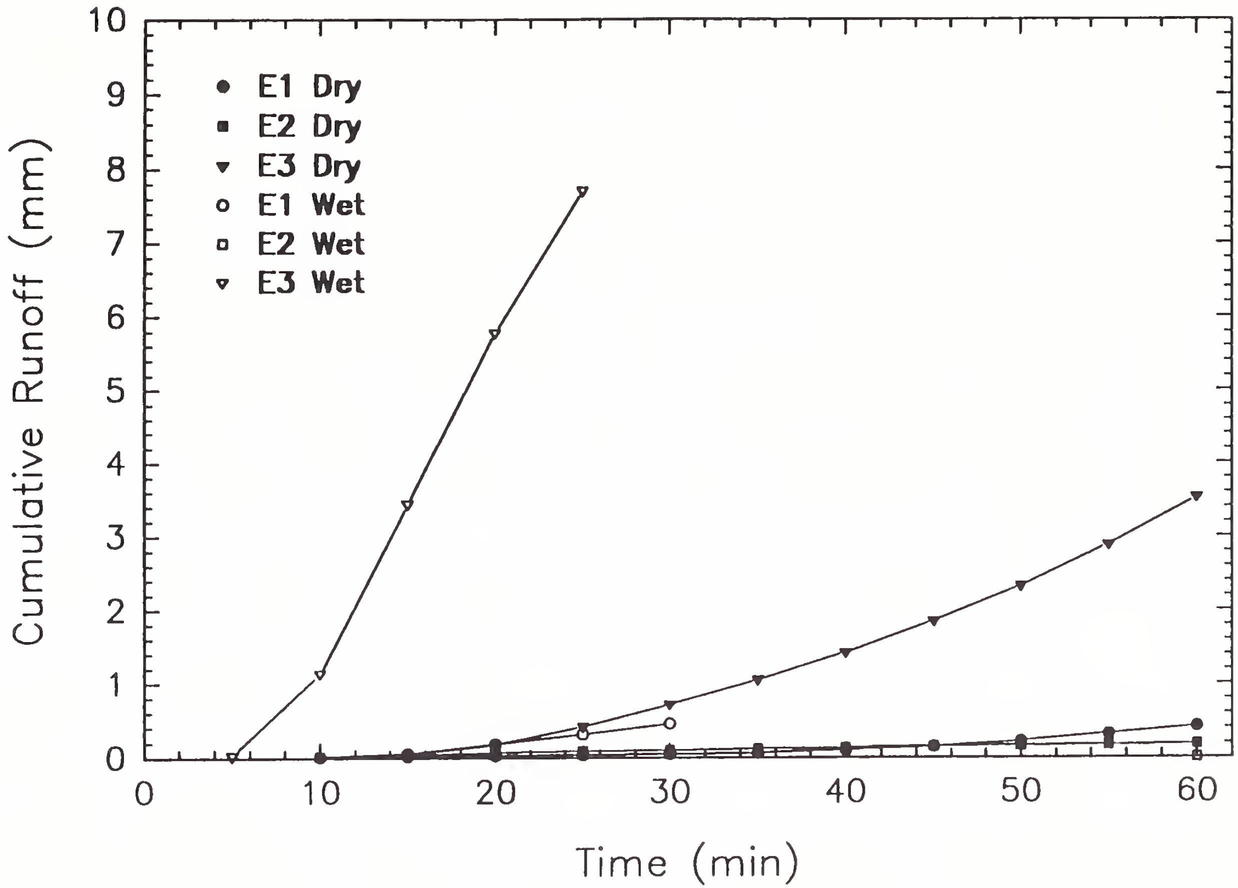


Figure 2. Cumulative runoff for sites E1, E2, and E3 in Kansas.

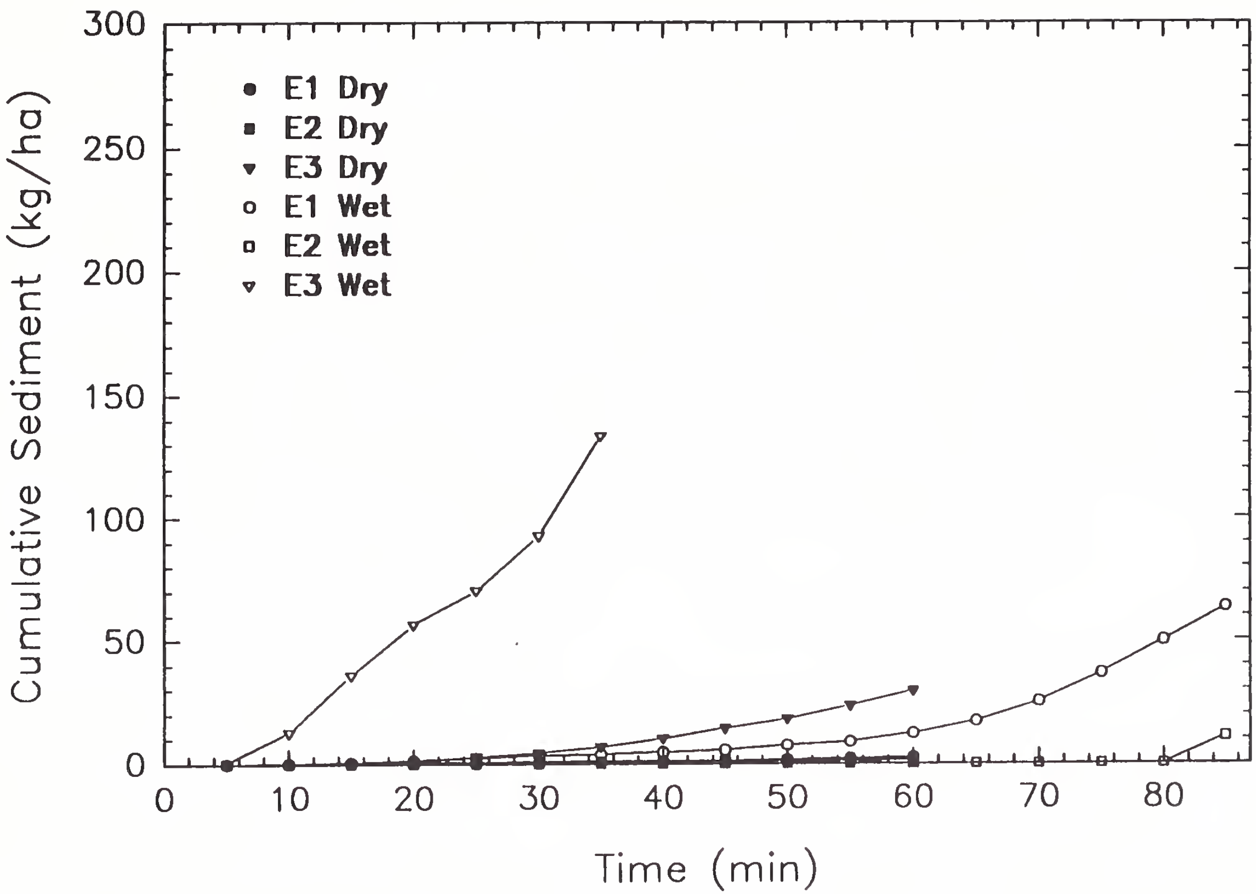


Figure 3. Cumulative sediment yield for sites E1, E2, and E3 in Kansas.

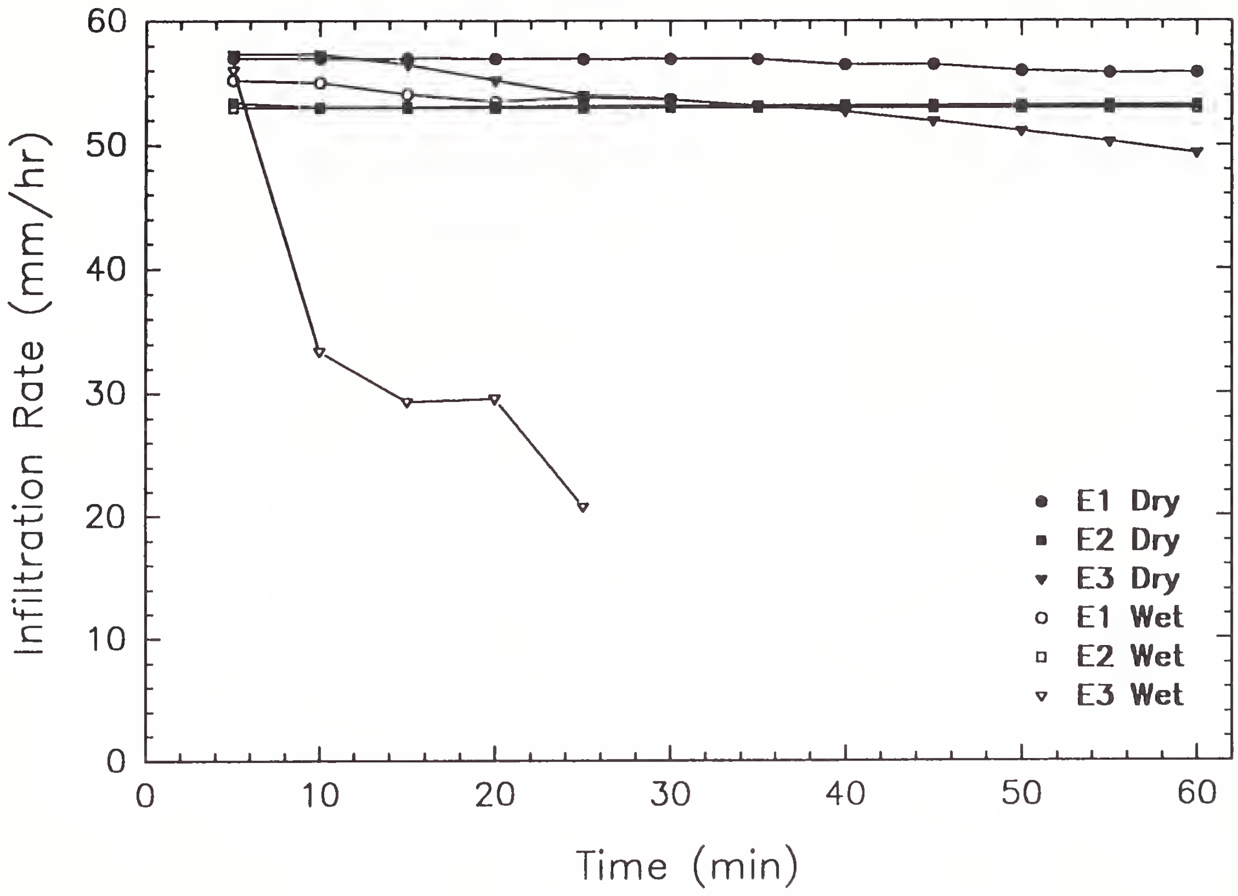


Figure 4. Instantaneous infiltration rate for sites E1, E2, and E3 in Kansas.

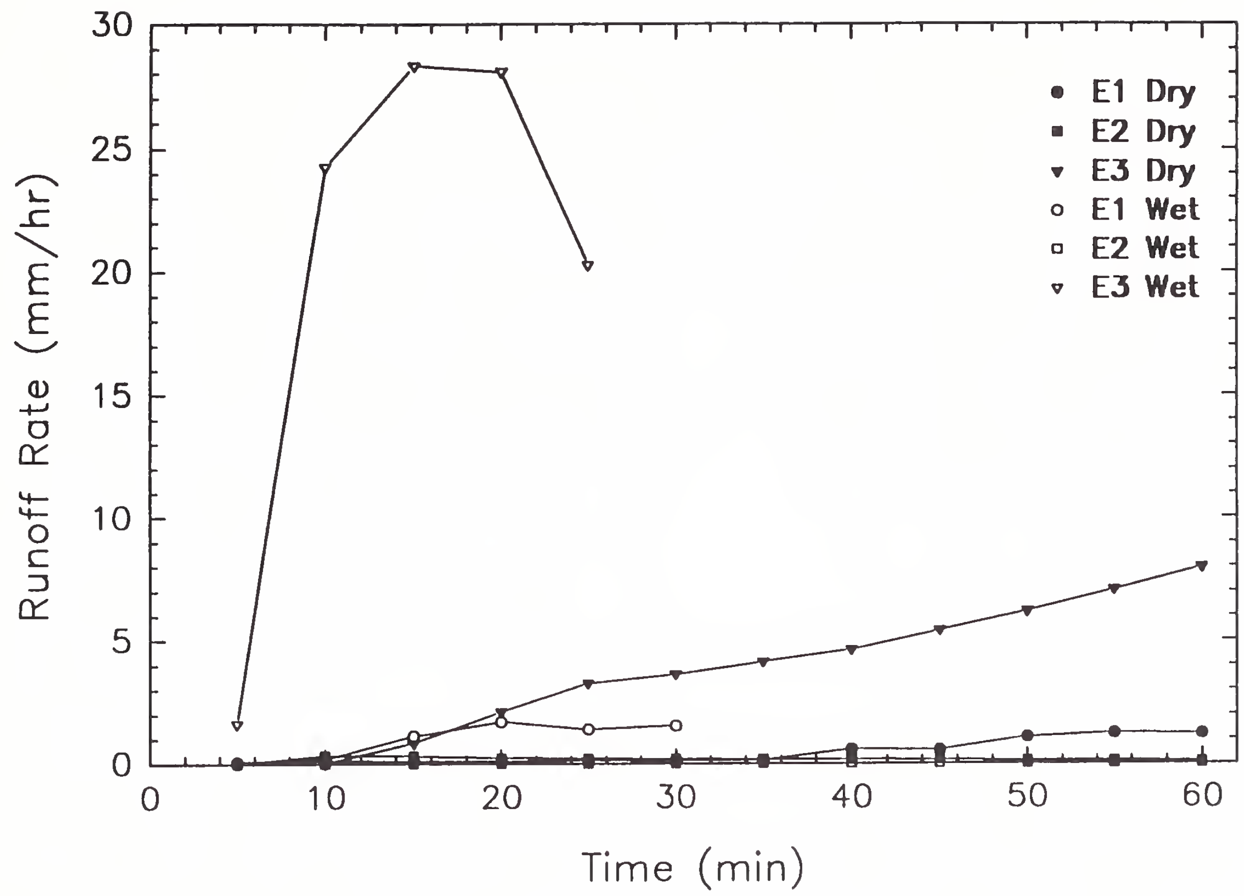


Figure 5. Instantaneous runoff rate for sites E1, E2, and E3 in Kansas.

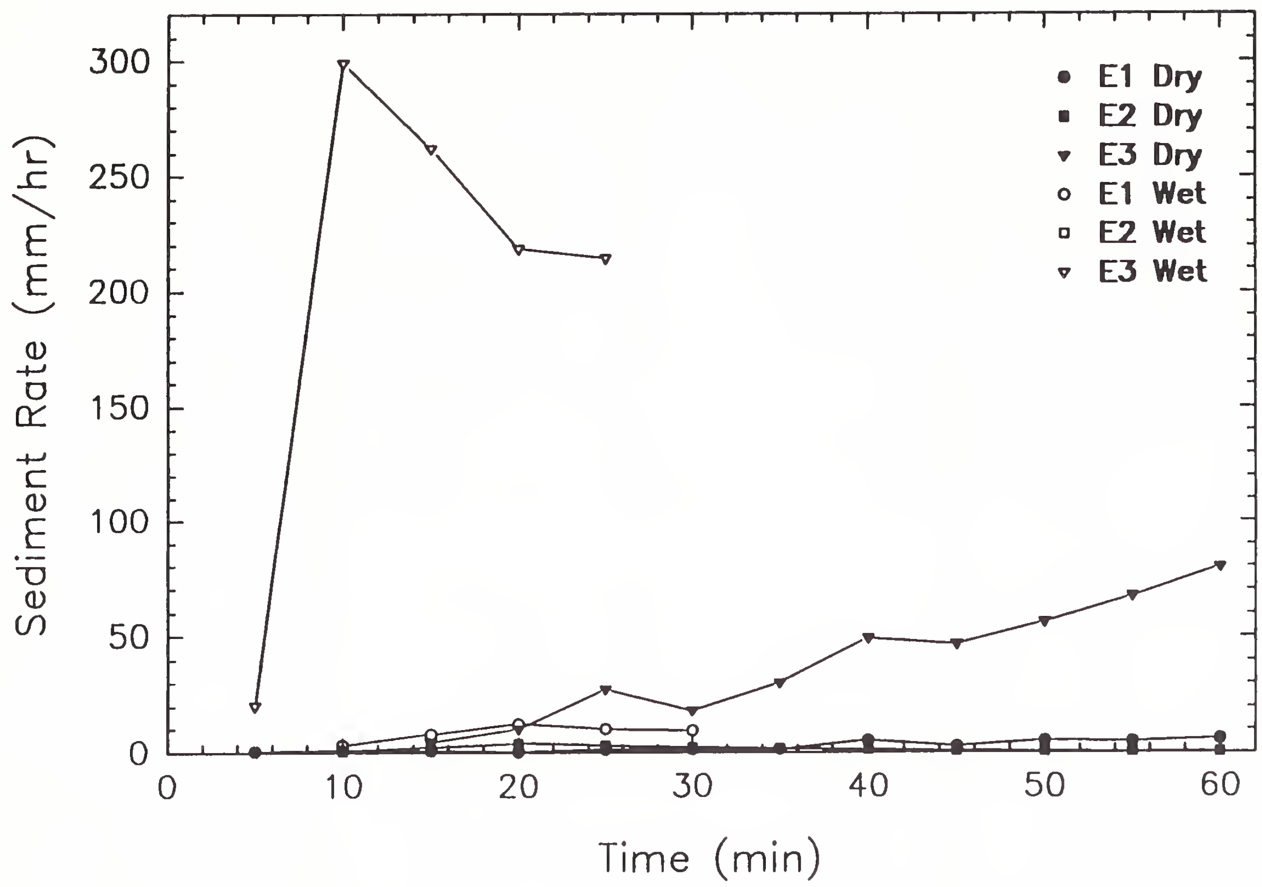


Figure 6. Instantaneous sediment yield rate for sites E1, E2, and E3 in Kansas.

# COLORADO Data Summaries

Range Site Description

The potential natural vegetation of these study sites is comprised of shortgrasses and midgrasses. About 80 to 90 percent of the community composition is grasses, 5 to 10 percent forbs, and 2 to 10 percent shrubs. Blue grama, western wheatgrass, green needlegrass, are the dominant grass species while needle-and-thread, buffalograss, sun sedge, and fourwing saltbush are secondary dominants. Other common species include bottlebrush squirreltail, sand dropseed, red threeawn, winterfat, plains pricklypear, scarlet globemallow, rush skeletonplant, and wooly indianwheat. Deterioration of the site is indicative of increases in blue grama, buffalograss, sand dropseed, red threeawn, ring muhly, tumblegrass, fringed sagebrush, broom snakeweed, and rubber rabbitbrush. Weedy invader species include cheatgrass, six weeks fescue, mustards, and Russian thistle.

This site provides excellent forage for livestock throughout the year and provides good forage for antelope, deer, and small mammals. The potential of this site for wildlife habitat is medium for antelope, jackrabbit, marsh hawk, golden eagle, ferruginous hawk, and coyote.

Location F1 was sampled, using the double-sampling method, and found to be in good range condition (70.4 percent). Blue grama composition was 67.0%. Out of the three locations, F1 had the highest percentage of western wheatgrass. F1 had 30.4 percent whereas site F2 and F3 had only traces. F1 had an average annual production of 1,415.3 pounds per acre. In comparison, if F1 was in excellent condition under a favorable year, it could produce 1,600 pounds per acre. There was an average of 2,130.3 pounds per acre of litter on F1. The estimated bare ground on F1 was 11.8 percent and the amount of cryptograms was minimum. The management practice used on F1 was an intense rotation grazing system.

Location F2 was sampled, using the double-sampling method, and found to be in fair range condition (44.2 percent). Out of the three locations, F2 had the highest percentage of blue grama (95%), sun sedge (2%) and squirreltail (1.5%). The average annual production for F2 was 832.1 pounds per acre. In comparison, if F2 was in excellent condition under a normal year, it could produce 1,000 pounds per acre. There was an average of 1,753.1 pounds per acre of litter on F2. The estimated bare ground on F2 was 18.8 percent and the amount of cryptograms was minimum. The management practice used on F2 was a rotation grazing system.

Location F3 was sampled, using the double-sampling method, and found to be in fair range condition (45.6 percent). Compared to F1, F3 had no western wheatgrass and compared to site F2, F3 had only 2.1 percent of red threeawn. The composition of site F3 was 46.6% blue grama and 53.3% buffalograss. The average annual production for F3 was 418.4 pounds per acre. In comparison, if F3 was in excellent condition under a normal year, it could produce 1,000 pounds per acre. There was an average of 2,257.6 pounds per acre of litter on F3. Litter was higher on this location due to cow manure. The estimated bare ground on F3 was 17.5 percent and amount of cryptograms was minimum.

Table 1. Colorado Site Characteristics.

| Variable | F1 Colorado<br>Proper Grazing Use | F2 Colorado<br>Proper Grazing Use | F3 Colorado<br>Heavy Grazing Use |
|---|---|---|---|
| Range Site | Loamy Plains | Loamy Plains | Loamy Plains |
| Avg. Annual Precip. (in) | 11 to 15.5 | 11 to 15.5 | 11 to 15.5 |
| Slope (%) | 7.5 | 8.0 | 7.0 |
| Elevation (ft) | 4400 | 4400 | 4300 |
| Aspect | South west | South west | South |
| Potential Climax Vegetation | Blue grama<br>Buffalograss | Blue grama<br>Buffalograss | Blue grama<br>Buffalograss |
| Range Condition | Good | Fair | Fair |
| Dominant Plants | Blue grama<br>Western wheatgrass<br>Buffalograss | Blue grama<br>Sun sedge<br>Squirreltail<br>Buffalograss | Buffalograss<br>Blue grama |
| Primary Use | Cow/calf, some horses; grazed spring, summer, and fall; short duration grazing for 8 years | Cow/calf some horses; grazed spring, summer, and fall; short duration grazing for 8 years | Cow/calf operation; grazed spring, summer, and fall; short duration grazing less than 1 year |
| Management History | No fertilizer, brush control, or burning | No fertilizer, brush control, or burning | No fertilizer, brush control, or burning |

Table 2. Colorado Vegetation and Plot Data.

| Variable | F1 Colorado Proper Grazing Use | F2 Colorado Proper Grazing Use | F3 Colorado Heavy Grazing Use |
|---|---|---|---|
| Grass Canopy Cover (CC) | 49.76 | 42.04 | 27.18 |
| Forb CC % | 0.71 | 0.24 | 0.20 |
| Shrub/H. Shrub CC % | 0.00 | 0.00 | 0.00 |
| Standing Dead CC% | 3.23 | 1.90 | 0.00 |
| Cacti CC% | 0.07 | 0.10 | 0.40 |
| Basal Vegetation % | 18.33 | 21.97 | 7.11 |
| Cryptogam <1cm ht. CC % | 0.34 | 6.22 | 6.22 |
| Cryptogam >1cm ht. CC % | 0.00 | 0.00 | 0.00 |
| Litter % | 76.90 | 57.31 | 68.64 |
| Bare Soil % | 4.42 | 14.49 | 17.86 |
| Rock % | 0.00 | 0.00 | 0.14 |
| Production (lbs/ac) | 1415.30 | 832.10 | 418.40 |
| Litter (lbs/ac) | 2130.30 | 1753.10 | 2257.60 |
| Random Roughness (std dev.) | 1.60 | 1.05 | 5.54 |

**Narrative Pedan descriptions for Colorado rainfall simulation sites are not yet available.**

Table 3. Average soil bulk density measured at 2 depths by the complience cavity method before rainfall simulation began and 24 hours after the very wet rainfall simulation ended for sites F1, F2, and F3 in Colorado.

| Site | Sampled | Depth (cm) | Bulk Density ($g/cm^3$) | Sample Size |
|---|---|---|---|---|
| F1 | Before Dry | 0.0-2.5 | 0.58 | 6 |
| | | 2.5-10.0 | 1.28 | 6 |
| | After Very Wet | 0.0-2.5 | 0.70 | 6 |
| | | 2.5-10.0 | 1.16 | 6 |
| F2 | Before Dry | 0.0-2.5 | 0.84 | 4 |
| | | 2.5-10.0 | 1.46 | 5 |
| | After Very Wet | 0.0-2.5 | . | 0 |
| | | 2.5-10.0 | . | 0 |
| F3 | Before Dry | 0.0-2.5 | 0.83 | 6 |
| | | 2.5-10.0 | 1.30 | 6 |
| | After Very Wet | 0.0-2.5 | 0.66 | 6 |
| | | 2.5-10.0 | 1.26 | 6 |

Table 4. Average depth to the wetting front measured at specified times before and after rainfall simulation runs for sites F1, F2, and F3 in Colorado.

| Site | When Sampled | Depth to Wetting Front (cm) | Sample Size |
|---|---|---|---|
| F1 | 30 m Before Wet Run | 29.0 | 2 |
| | After Wet Run | 31.7 | 6 |
| | 30 m After Very Wet Run | 50.7 | 6 |
| F2 | 30 m Before Wet Run | 23.0 | 6 |
| | After Wet Run | 33.2 | 6 |
| | 30 m After Very Wet Run | 45.8 | 5 |
| F3 | 30 m Before Wet Run | 26.7 | 6 |
| | After Wet Run | 38.8 | 6 |
| | 30 m After Very Wet Run | 48.3 | 6 |

Table 5. Average root biomass measured at 2 depths for sites F1, F2, and F3 in Colorado.

| Site | Landscape Position | Depth (cm) | Root Biomass (kg/ha) | Sample Size |
|---|---|---|---|---|
| F1 | Basal | 0.0-2.5 | 1108.65 | 6 |
| | | 2.5-10.0 | 291.15 | 6 |
| F2 | Basal | 0.0-2.5 | 2577.09 | 6 |
| | | 2.5-10.0 | 324.87 | 6 |
| F3 | Basal | 0.0-2.5 | 2156.82 | 6 |
| | | 2.5-10.0 | 880.14 | 6 |

Table 6. Average hydrologic characteristics of dry and wet antecedent moisture condition rainfall simulation runs for sites F1, F2, and F3 in Colorado.

| Site | Cumulative Runoff (mm) | Cumulative Infiltration (mm) | Cumulative Sediment Yield (kg/ha) | Runoff Rate (mm/hr) | Infiltration Rate (mm/hr) | Sediment Yield Rate (kg/ha/hr) |
|---|---|---|---|---|---|---|
| At 60 Minutes During Dry Runs | | | | | | |
| F1 | 16.09 | 43.44 | 124.64 | 25.34 | 33.97 | 202.16 |
| F2 | 18.56 | 39.52 | 118.22 | 25.28 | 32.80 | 93.65 |
| F3 | 19.35 | 29.51 | 490.13 | 18.06 | 30.80 | 272.39 |
| At 30 Minutes During Wet Runs | | | | | | |
| F1 | 9.32 | 19.72 | 45.17 | 33.93 | 24.15 | 88.80 |
| F2 | 7.03 | 21.90 | 69.39 | 23.43 | 34.43 | 194.93 |
| F3 | 10.69 | 16.96 | 145.27 | 32.97 | 22.31 | 336.64 |

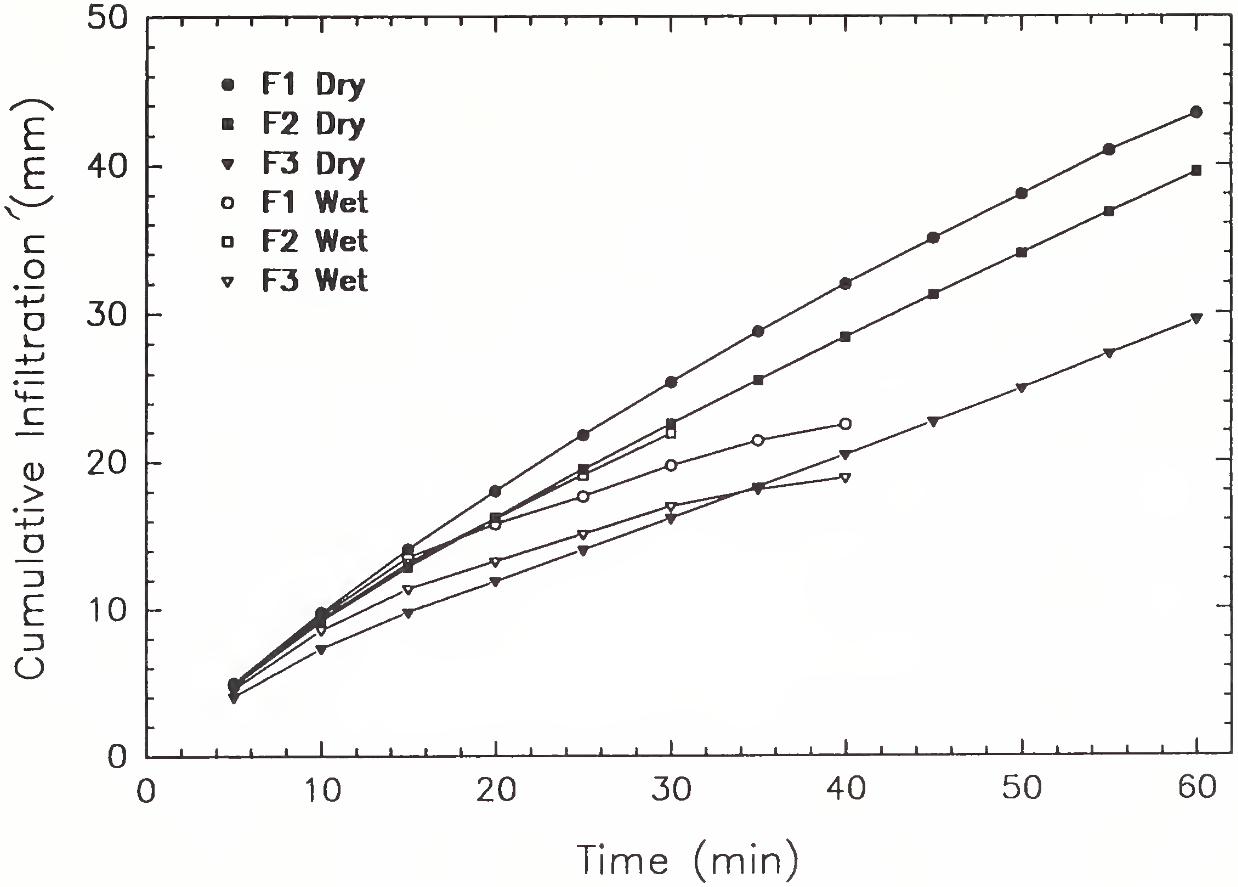


Figure 1. Cumulative infiltration for sites F1, F2, and F3 in Colorado.

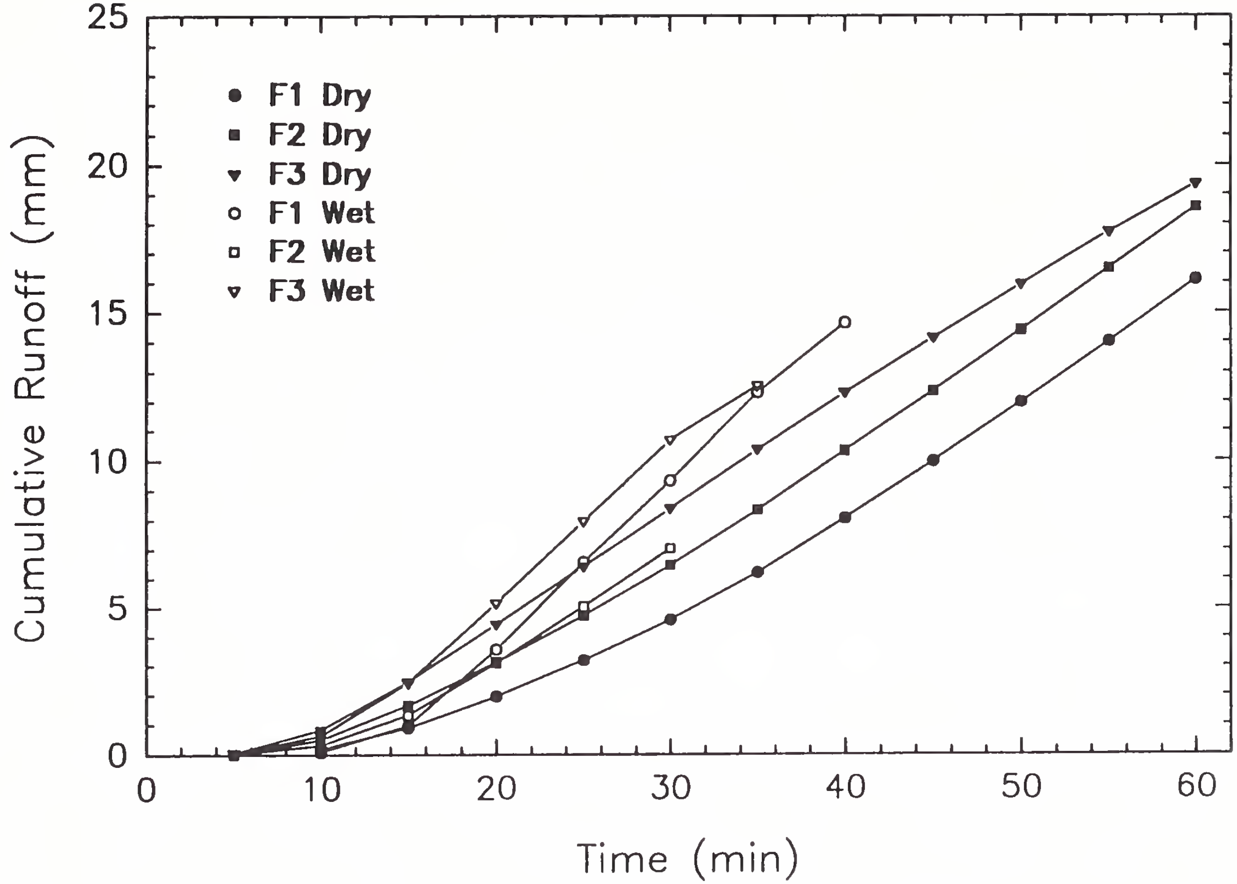


Figure 2. Cumulative runoff for sites F1, F2, and F3 in Colorado.

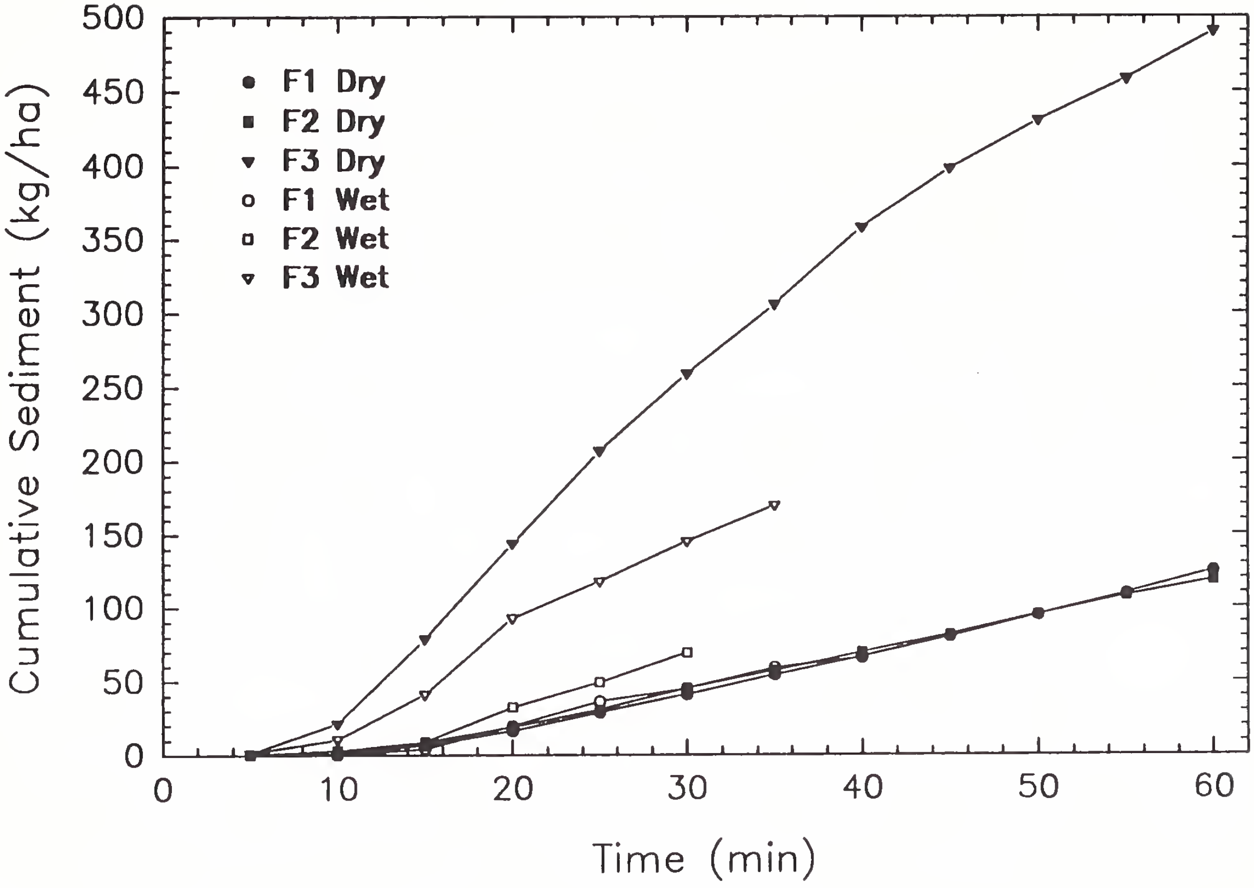


Figure 3. Cumulative sediment yield for sites F1, F2, and F3 in Colorado.

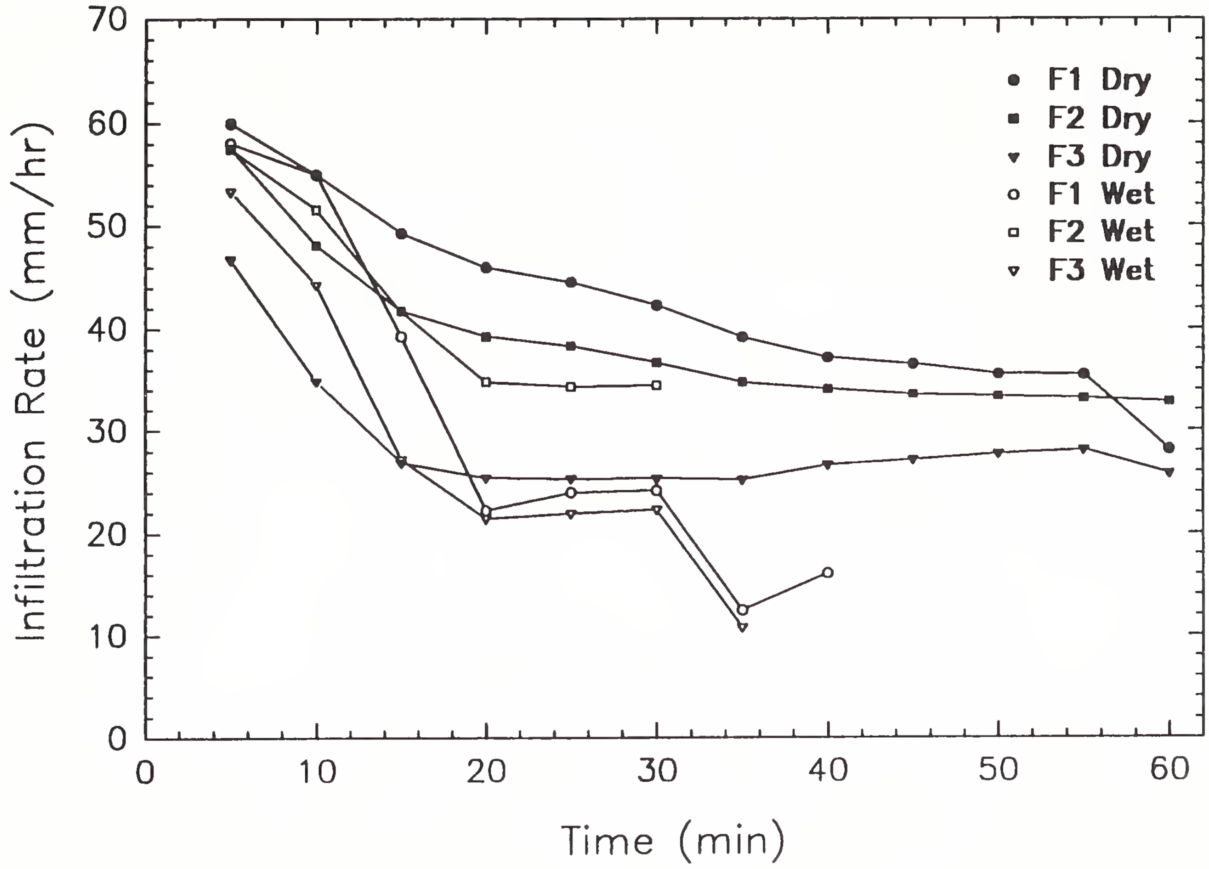


Figure 4. Instantaneous infiltration rate for sites F1, F2, and F3 in Colorado.

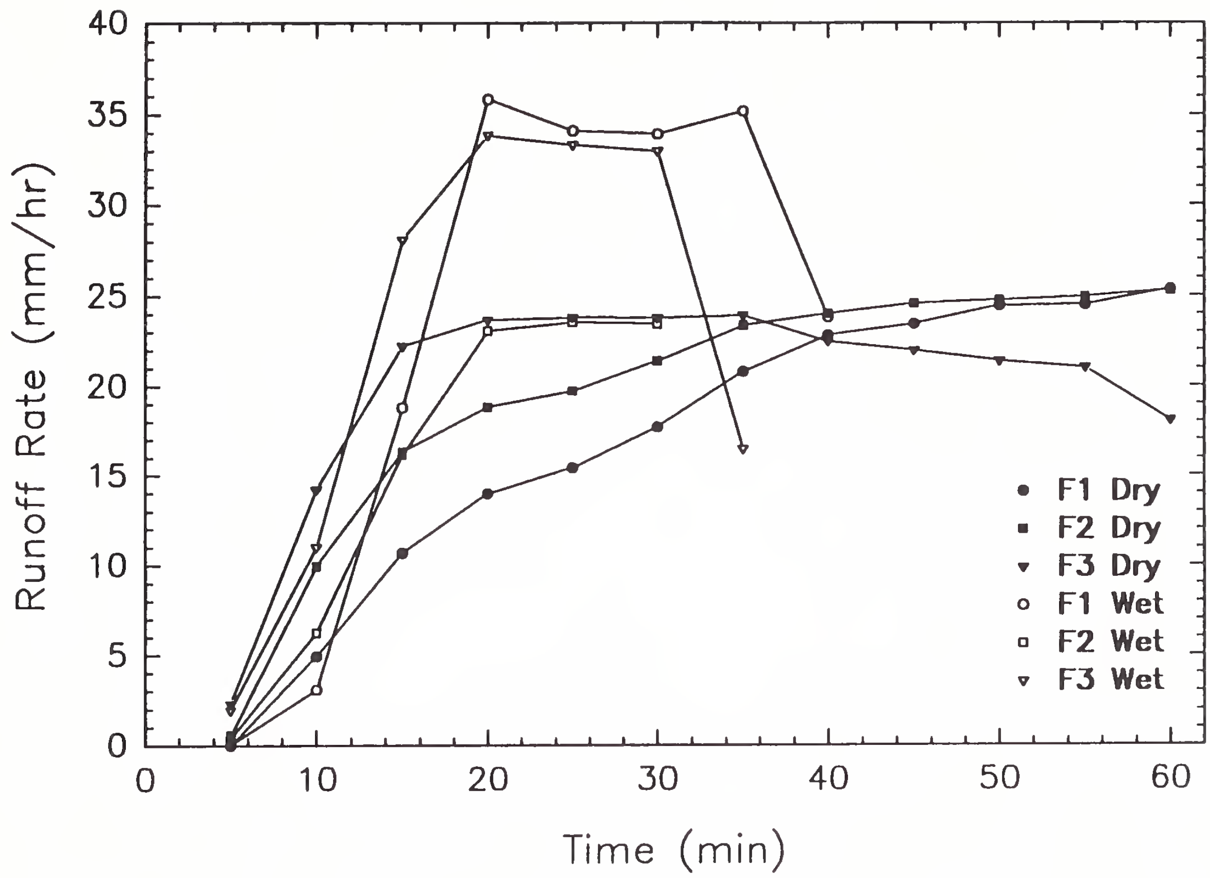


**Figure 5. Instantaneous runoff rate for sites F1, F2, and F3 in Colorado.**

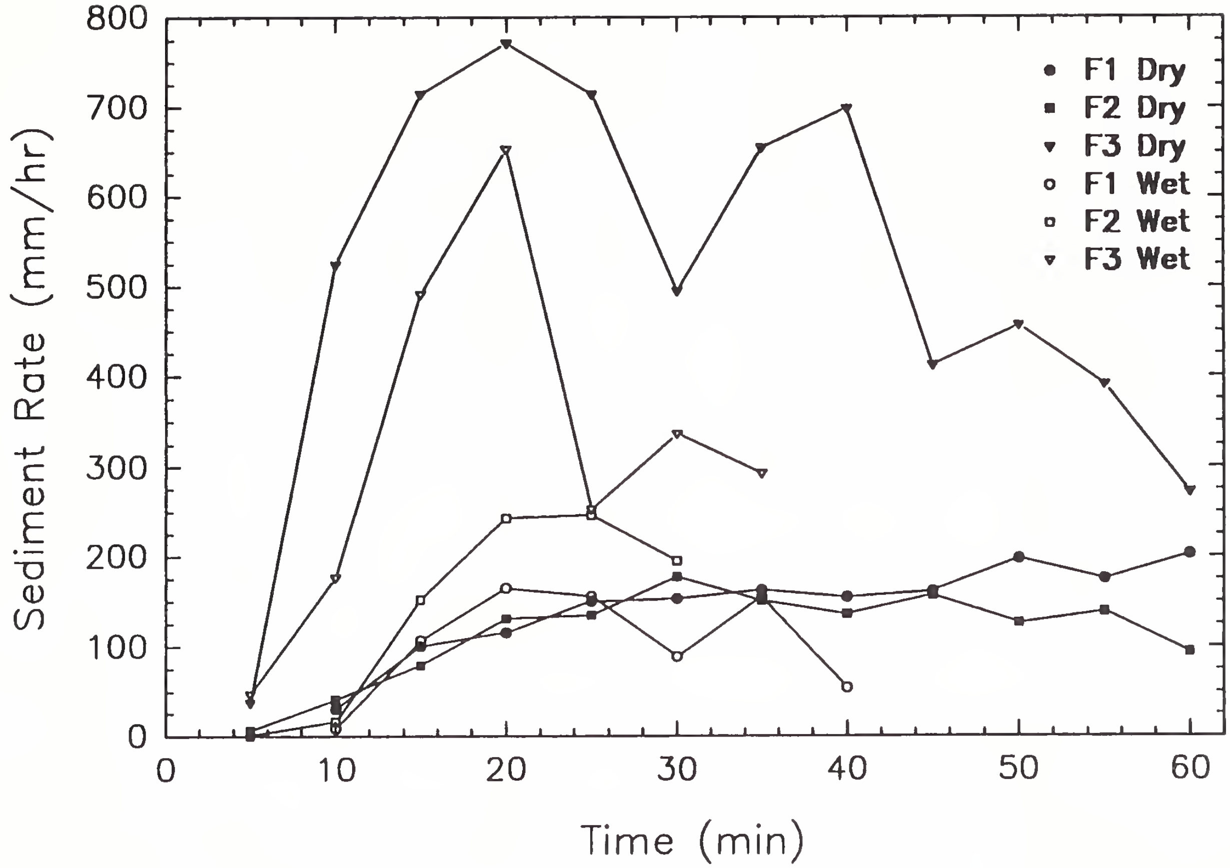


Figure 6. Instantaneous sediment yield rate for sites F1, F2, and F3 in Colorado.

# WYOMING Data Summaries

Range Site Description

The potential natural vegetation of these study sites is comprised of midgrasses, mainly rhizomatous western wheatgrass, green needlegrass, needle-and-thread, and blue grama. About 75% of the plant composition is grasses or grass-like plants, 15% forbs, and 10% woody plants. Common forbs include prairie coneflower, penstemmons, biscuitroot, scurfpea spp., asters, milkvetch, buckwheat, lupine, and fringed sagewort. Woody plants include big sagebrush and winterfat. As range condition deteriorates, blue grama and big sagebrush increase. Further deterioration and a loss of native perennial grasses results in cheatgrass establishment (invasion) which can become the dominant species on the site.

This site can provide good forage throughout the year for livestock. This site can provide adequate habitat for antelope, mule deer, coyote, fox, jackrabbit, sage grouse, and other upland birds and small mammals.

Location G1 was sampled, using the double-sampling method, and found to be in fair range condition (36.4 percent). Out of the three locations, G1 had the highest percentage of cactus (prickly pear). G1 had 32.9 percent whereas G2 had 3.4 percent cactus and G3 had 4.2 percent. G1 was in fair condition mostly because of the cactus. Cactus is not considered a climax species in the site description. Cactus also made up allot of production on G1 but only the annual production was accounted for. Unlike grasses or grasslike plants where last year growth is considered litter or decay, the last year growth of cactus plants, most of the time, is still living material occupying allot of above ground space. Annual production calculation for cactus is 10 percent of the actual weight of the entire plant. On G1 the average annual production for cactus was 392.7 pounds per acre, therefore the total amount for the location was 3,927.0 pounds per acre. The average annual production for G1 was 1,155 pounds per acre. In comparison, if G1 was in excellent condition under a normal year, it could produce about 1,200 pounds per acre. There was an average of 483.5 pounds per acre of litter on G1. The estimated bare ground on G1 was 27 percent and the amount of cryptograms was high.

Location G2 was sampled, using the double-sampling method, and found to be in fair range condition (40.7 percent). The dominant species at location G1 were cheatgrass (36%), needle-and-thread (25%), blue grama (22%), and thread leaf sedge (8%). Out of the three locations, G2 had the highest percentage of cheatgrass. G2 had 36.3 percent whereas G1 had .2 percent and G3 had only traces. G2 was in fair condition mostly because of the cheatgrass. Cheatgrass is not considered a climax species in the site description. The average annual production for G2 was 1,938.5 pounds per acre due to the high amount of cheatgrass. In comparison, if G2 was in excellent condition under a favorable year, it could produce about 1,500 pounds per acre. There was an average of 931.2 pounds per acre of litter on G2. The estimated bare ground on G2 was 15 percent and the amount of cryptograms was minimum.

Location G3 was sampled, using the double-sampling method, and found to be in fair range condition (43.4 percent). The dominant species at location G3 were sunsedge (40%), needle-and-thread (35%), blue grama (15%), and western wheatgrass (3.5%). Compared to G1, G3 had very little cactus and compared to G2, G3 had only traces of cheatgrass. There were few invader species on G3 but it had a high degree of pedestalling between the

plants. This pedestalling caused the vegetation density to be lower, therefore less productive. The average annual production for G3 was 804.0 pounds per acre, which was much less than location G1's 1,155 pounds per acre and G2's 1,938.5 pounds per acre. In comparison, if G3 was in excellent condition under a normal year, it could produce about 1,200 pounds per acre. There was an average of 209.6 pounds per acre of litter on G3. The estimated bare ground on G3 was 57 percent, which was much more than G1's 27 percent and G2's 15 percent. The amount of cryptograms on G3 was minimum.

Table 1. Wyoming Site Characteristics.

| Variable | G1 Wyoming<br>Heavy Grazing Use | G2 Wyoming<br>Heavy Grazing Use | G3 Wyoming<br>Heavy Grazing Use |
|---|---|---|---|
| Range Site | Loamy Plains | Loamy Plains | Loamy Plains |
| Avg. Annual Precip. (in) | 10 to 14 | 10 to 14 | 10 to 14 |
| Slope (%) | 7.0 | 8.0 | 7.0 |
| Elevation (ft) | 4200 | 4200 | 4200 |
| Aspect | East | East | East |
| Potential Climax Vegetation | Western wheatgrass<br>Green needlegrass | Western wheatgrass<br>Green needlegrass | Western wheatgrass<br>Green needlegrass |
| Range Condition | Fair | Fair | Fair |
| Dominant Plants | Pricklypear cactus<br>Needle and Thread<br>Threadleaf sedge | Cheatgrass<br>Needle and Thread<br>Blue grama<br>Threadleaf sedge | Threadleaf sedge<br>Needle and thread<br>Blue grama<br>Western wheatgrass |
| Primary Use | Cow/calf operation; spring, summer, or fall in rotation | Cow/calf some horses; used year round with a rotation system | Cow/calf some horses;<br>used year round with a rotation system |
| Management History | No fertilizer, brush control, or burning | No fertilizer, brush control, or burning | No fertilizer, brush control, or burning |

Table 2. Wyoming Vegetation Data.

| Variable | G1 Wyoming Heavy Grazing Use | G2 Wyoming Heavy Grazing Use | G3 Wyoming Heavy Grazing Use |
|---|---|---|---|
| Grass Canopy Cover (CC) | 5.95 | 53.88 | 27.62 |
| Forb CC % | 0.99 | 0.92 | 2.48 |
| Shrub/H. Shrub CC % | 0.07 | 0.14 | 0.10 |
| Standing Dead CC% | 0.88 | 0.17 | 1.73 |
| Cacti CC % | 2.89 | 0.61 | 0.44 |
| Basal Vegetation % | 11.84 | 3.06 | 8.20 |
| Cryptogam <1cm ht. CC % | 24.63 | 0.14 | 5.61 |
| Cryptogam >1cm ht. CC % | 0.20 | 0.14 | 0.37 |
| Litter % | 40.00 | 77.42 | 32.07 |
| Bare Soil % | 23.23 | 18.95 | 53.10 |
| Rock % | 0.00 | 0.00 | 0.41 |
| Production (lbs/ac) | 1155.60 | 1938.50 | 804.00 |
| Litter (lbs/ac) | 483.50 | 931.20 | 209.60 |
| Random Roughness (std dev.) | 19.04 | 20.20 | 22.50 |

# NARRATIVE PEDON DESCRIPTION

Pedon: Kishona
Soil Survey Number S91-WY-045-003
Location: Weston County, Wyoming
T. 44 N., R. 63 W., Section 29.
Latitude: 43-47-30-N
Physiography: Fan In
Microrelief: linear
Slope: 7% east facing
Precipitation: cm - Moisture Regime.
Water Table Depth:
Drainage: Well drained
Stoniness: Erosion or Deposition: Slight
Parent Material: residuum from sandstone-shale material
Classification: Fine-loamy, mixed, mesic Ustic Torriorthent
Diagnostic Horizons:
Described By: C. Franks, J. Warner
Vegetation: sedge, blue grama, prickly pear.

NSSL Pedon Number: 91P0987
Print Date: 10/08/92

Longitude: 104-22-30-W

Elevation: 1279 m MSL

Permeability: Moderately slow
Land Use:
Runoff:

Sample Date: 7/91

A -- 0 to 15 cm; dark brown (10YR 3/3) moist loam; weak fine granular structure; very friable, nonsticky, nonplastic; common very fine and many fine roots; common fine tubular pores; slightly effervescent; clear smooth boundary.
91P6185

Bw1 -- 15 to 48 cm; brown to dark brown (10YR 4/3) moist loam; weak fine granular structure; very friable, slightly sticky, slightly plastic; common very fine and fine roots; common fine tubular pores; slightly effervescent; clear smooth boundary.
91P6186

Bk1 -- 48 to 71 cm; brown (10YR 5/3) moist loam; weak fine and medium subangular blocky structure parting to weak medium prismatic; very friable, slightly sticky, slightly plastic; few very fine roots; common fine tubular pores; strongly effervescent; gradual wavy boundary.
91P6187

Bk2 -- 71 to 97 cm; brown (10YR 5/3) moist loam; weak medium subangular blocky structure; very friable, slightly sticky, slightly plastic; few very fine roots; common fine tubular pores; strongly effervescent; clear wavy boundary.
91P6188

Bk3 -- 97 to 114 cm; brown (10YR 5/3) moist loam; massive; very friable, slightly sticky, slightly plastic; few very fine roots; common fine tubular pores; strongly effervescent.
91P6189

Akb --114 to 135 cm; dark grayish brown (10YR 4/2) moist loam; massive; very friable, slightly sticky, slightly plastic; few very fine roots; common fine tubular pores; strongly effervescent; clear wavy boundary.
91P6190

Bkb --135 to 140 cm; brown to dark brown (10YR 4/3) moist loam; massive; very friable, slightly sticky, slightly plastic; strongly effervescent.
few thin CaCO3 concretions; 0-1" (91P6192) is a subsample
91P6191

# NARRATIVE PEDON DESCRIPTION

Pedon: Kishona
Soil Survey Number S91-WY-045-002
Location: Weston County, Wyoming
T. 44 N., R. 63 W., Section 27.
Latitude: 43-45-00-N
Physiography: Fan in
Microrelief: linear
Slope: 7% north facing
Precipitation: cm - Moisture Regime.
Drainage: Well drained
Stoniness: Erosion or Deposition: Moderate
Parent Material: residuum from sandstone-shale material
Classification: Fine-loamy, mixed, mesic Ustic Torriorthent
Diagnostic Horizons:
Described By: J. Warner, C. Franks, P. Dern
Vegetation: needle and thread, cheatgrass, sedge, blue grama.

NSSL Pedon Number: 91P0982
Print Date: 10/08/92

Longitude: 104-22-30-W

Elevation: 1228 m MSL

Land Use:
Runoff:

Sample Date: 7/91

A -- 0 to 15 cm; dark grayish brown (2.5Y 4/2) moist clay loam; weak fine granular structure; very friable, nonsticky, nonplastic; many very fine and fine roots; few fine tubular pores; slightly effervescent; clear smooth boundary.
91P6161

AB -- 15 to 36 cm; (2.5Y 5/3) moist clay loam; weak fine granular structure parting to weak medium granular; very friable, nonsticky, nonplastic; common very fine and many fine roots; few fine tubular pores; slightly effervescent; clear smooth boundary.
91P6162

Bw -- 36 to 64 cm; (2.5Y 5/3) moist clay loam; weak fine and medium subangular blocky structure; very friable, nonsticky, nonplastic; few very fine and common fine roots; few fine tubular pores; slightly effervescent; abrupt wavy boundary.
91P6163

Ab -- 64 to 89 cm; dark grayish brown (2.5Y 4/2) moist clay loam; weak medium prismatic structure parting to weak fine subangular blocky; very friable, slightly sticky, slightly plastic; few very fine and common fine roots; few fine tubular pores; slightly effervescent; clear smooth boundary.
91P6164

Bwb -- 89 to 107 cm; (2.5Y 5/3) moist clay loam; weak medium prismatic structure parting to weak fine and medium subangular blocky; very friable, slightly sticky, slightly plastic; few very fine roots; few fine tubular pores; slightly effervescent; gradual wavy boundary.
91P6165

Bk1 --107 to 130 cm; (2.5Y 5/3) moist clay loam; massive; very friable, slightly sticky, slightly plastic; few very fine roots; slightly effervescent; clear smooth boundary.
91P6166

Bk2 --130 to 155 cm; (2.5Y 5/3) moist clay loam; massive; firm, sticky, plastic; few very fine roots; few fine tubular pores; strongly effervescent.
0-1" (91P6168) is a subsample
91P6167

# NARRATIVE PEDON DESCRIPTION

Pedon: Kishona
Soil Survey Number S91-WY-045-001
Location: Weston County, Wyoming
T. 44 N., R. 63 W., Section 27.
Latitude: 43-45-00-N
Physiography: Fan in
Microrelief: linear
Slope: 7% north facing
Precipitation: cm - Moisture Regime.
Water Table Depth:
Drainage: Well drained
Stoniness: Erosion or Deposition: Moderate
Parent Material: residuum from sandstone-shale material
Classification: Fine-loamy, mixed, mesic Ustic Torriorthent
Diagnostic Horizons:
Described By: J. Warner, C. Franks, P. Dern
Vegetation: needle and thread, sedge.

NSSL Pedon Number: 91P0977
Print Date: 10/08/92

Longitude: 104-22-30-W

Elevation: 1228 m MSL

Permeability: Moderately slow
Land Use:
Runoff:

Sample Date: 7/91

A -- 0 to 10 cm; dark grayish brown (2.5Y 4/2) moist very fine sandy loam; weak fine granular structure; slightly hard, very friable, nonsticky, nonplastic; many very fine and fine roots; few fine tubular pores; slightly effervescent; 1 percent pebbles; clear smooth boundary.
91P6137

Bw1 -- 10 to 25 cm; (2.5Y 4/3) moist loam; weak fine subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; many very fine and fine roots; few fine tubular pores; slightly effervescent; 1 percent pebbles; clear smooth boundary.
91P6138

Bw2 -- 25 to 41 cm; (2.5Y 5/3) moist loam; weak medium subangular blocky structure parting to weak fine subangular blocky; slightly hard, very friable, nonsticky, nonplastic; few very fine and many fine roots; few fine tubular pores; slightly effervescent; 1 percent pebbles; clear wavy boundary.
91P6139

C1 -- 41 to 71 cm; (2.5Y 5/3) moist loam; weak medium subangular blocky structure parting to weak fine subangular blocky; slightly hard, very friable, nonsticky, nonplastic; few very fine and fine roots; few fine tubular pores; slightly effervescent; 1 percent pebbles; gradual wavy boundary.
few soft masses of $CaCO_3$
91P6140

C2 -- 71 to 102 cm; (2.5Y 5/3) moist loam; massive; slightly hard, very friable, nonsticky, nonplastic; few very fine and fine roots; few fine tubular pores; slightly effervescent; 1 percent pebbles; abrupt wavy boundary.
few soft masses of $CaCO_3$
91P6141

C3 --102 to 117 cm; (2.5Y 5/3) moist loam; massive; slightly hard, very friable, nonsticky, nonplastic; few very fine roots; few fine tubular pores; slightly effervescent; 1 percent pebbles; abrupt wavy boundary.
91P6142

Cr --117 to 157 cm;; massive.
shale
91P6143

Table 3. Selected soil horizon characteristics of the master soil pedon sampled for site G1, Wyoming - Kishona loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragment (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-14 | 58.1 | 30.5 | 11.4 | L | 1.30 | 1.29 | . | 17.8 | 6.2 |
| Bw1 | 14-48 | 48.5 | 29.1 | 22.4 | L | 1.37 | 0.66 | . | 17.7 | 10.8 |
| Bk1 | 48-71 | 43.7 | 32.4 | 23.9 | L | 1.42 | 0.60 | 1 | 19.7 | 10.1 |
| Bk2 | 71-97 | 42.6 | 35.3 | 22.1 | L | 1.45 | 0.39 | . | 16.7 | 9.3 |
| Bk3 | 97-115 | 49.9 | 30.0 | 20.1 | L | 1.52 | 0.26 | . | 15.8 | 7.8 |
| AkB | 115-136 | 49.2 | 30.4 | 20.4 | L | 1.49 | 0.23 | . | 14.5 | 8.0 |
| BkB | 136-140 | 48.3 | 32.2 | 19.5 | L | 1.46 | 0.23 | . | 19.8 | 8.1 |

[1]Key to texture; L=Loam.

Table 4. Selected soil horizon characteristics of the master soil pedon sampled for site G2, Wyoming - Kishona loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragments (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-14 | 47.1 | 29.2 | 23.7 | L | 1.38 | 1.76 | . | 29.5 | 10.5 |
| AB | 14-36 | 64.8 | 21.0 | 14.2 | L | 1.45 | 0.57 | . | 18.6 | 6.9 |
| Bw | 36-63 | 72.8 | 15.1 | 12.1 | L | 1.57 | 0.38 | Tr | 16.8 | 5.8 |
| AB | 63-88 | 58.1 | 23.2 | 18.7 | L | 1.41 | 0.70 | . | 13.5 | 8.6 |
| BwB | 88-107 | 44.9 | 31.1 | 24.0 | L | 1.40 | 0.69 | Tr | 22.8 | 10.8 |
| Bk1 | 107-130 | 50.5 | 27.4 | 22.1 | L | 1.43 | 0.50 | . | 19.8 | 9.5 |
| Bk2 | 130-155 | 58.1 | 23.0 | 18.9 | L | . | 0.30 | . | . | 8.6 |

[1]Key to texture; L=Loam.

Table 5. Selected soil horizon characteristics of the master soil pedon sampled for site G3, Wyoming - Kishona loam.

| Horizon | Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Texture[1] | Bulk Density (g/cm3) | Organic Carbon (%) | Coarse Fragments (%) | 1/3 bar Water (cm/cm) | 15 bar Water (cm/cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-10 | 60.1 | 26.3 | 13.6 | VFSL | 1.25 | 1.30 | . | 17.7 | 8.0 |
| Bw1 | 10-24 | 66.0 | 20.8 | 13.2 | L | 1.48 | 0.64 | Tr | 15.8 | 8.2 |
| Bw2 | 24-41 | 64.6 | 22.0 | 13.4 | L | 1.51 | 0.43 | Tr | 16.2 | 8.4 |
| C1 | 41-72 | 61.1 | 22.9 | 16.0 | L | 1.54 | 0.24 | Tr | 14.6 | 8.7 |
| C2 | 72-100 | 57.5 | 24.8 | 17.7 | L | 1.43 | 0.21 | 2 | 20.1 | 9.8 |
| C3 | 100-117 | 54.6 | 25.9 | 19.5 | L | . | 0.21 | 31 | . | 10.4 |
| CR | 117-158 | 16.4 | 49.0 | 34.6 | . | . | 0.17 | . | . | 23.7 |

[1]Key to texture; VFSL=Ver fine sandy-loam, L=Loam.

Table 6. Average soil bulk density measured at 2 depths by the complience cavity method before rainfall simulation began and 24 hours after the very wet rainfall simulation ended for sites G1, G2, and G3 in Wyoming.

| Site | Sampled | Depth (cm) | Bulk Density ($g/cm^3$) | Sample Size |
|---|---|---|---|---|
| G1 | Before Dry | 0.0-2.5 | 0.72 | 6 |
| | | 2.5-10.0 | 1.44 | 6 |
| | After Very Wet | 0.0-2.5 | 1.00 | 6 |
| | | 2.5-10.0 | 1.35 | 6 |
| G2 | Before Dry | 0.0-2.5 | 0.93 | 6 |
| | | 2.5-10.0 | 1.31 | 6 |
| | After Very Wet | 0.0-2.5 | 0.76 | 6 |
| | | 2.5-10.0 | 1.26 | 6 |
| G3 | Before Dry | 0.0-2.5 | 0.77 | 6 |
| | | 2.5-10.0 | 1.23 | 6 |
| | After Very Wet | 0.0-2.5 | 0.95 | 6 |
| | | 2.5-10.0 | 1.29 | 6 |

Table 7. Average depth to the wetting front measured at specified times before and after rainfall simulation runs for sites G1, G2, and G3 in Wyoming.

| Site | When Sampled | Depth to Wetting Front (cm) | Sample Size |
|---|---|---|---|
| G1 | 30 m Before Wet Run | 26.0 | 6 |
| | After Wet Run | 62.8 | 6 |
| | 30 m After Very Wet Run | 74.5 | 6 |
| G2 | 30 m Before Wet Run | 34.3 | 6 |
| | After Wet Run | 33.3 | 6 |
| | 30 m After Very Wet Run | 55.2 | 6 |
| G3 | 30 m Before Wet Run | 23.8 | 6 |
| | After Wet Run | 26.7 | 6 |
| | 30 m After Very Wet Run | 43.0 | 6 |

Table 8. Average root biomass measured at 2 depths for sites G1, G2, and G3 in Wyoming.

| Site | Landscape Position | Depth (cm) | Root Biomass (kg/ha) | Sample Size |
|---|---|---|---|---|
| G1 | Basal | 0.0-2.5 | 3394.11 | 3 |
| | | 2.5-10.0 | 634.27 | 3 |
| | Interspace | 0.0-2.5 | 618.85 | 3 |
| | | 2.5-10.0 | 278.21 | 3 |
| G2 | Basal | 0.0-2.5 | 2991.68 | 6 |
| | | 2.5-10.0 | 408.60 | 6 |
| | Interspace | 0.0-2.5 | 410.26 | 2 |
| | | 2.5-10.0 | 84.40 | 2 |
| G3 | Basal | 0.0-2.5 | 1384.62 | 6 |
| | | 2.5-10.0 | 867.21 | 6 |
| | Interspace | 0.0-2.5 | 252.73 | 6 |
| | | 2.5-10.0 | 215.87 | 6 |

Table 9. Average hydrologic characteristics of dry and wet antecedent moisture condition rainfall simulation runs for sites G1, G2, and G3 in Wyoming.

| Site | Cumulative Runoff (mm) | Cumulative Infiltration (mm) | Cumulative Sediment Yield (kg/ha) | Runoff Rate (mm/hr) | Infiltration Rate (mm/hr) | Sediment Yield Rate (kg/ha/hr) |
|---|---|---|---|---|---|---|
| At 60 Minutes During Dry Runs | | | | | | |
| G1 | 3.21 | 47.11 | 36.31 | 2.05 | 48.61 | 5.94 |
| G2 | 4.76 | 52.02 | 52.38 | 3.96 | 52.82 | 19.67 |
| G3 | 18.08 | 39.32 | 317.95 | 25.41 | 31.99 | 318.65 |
| At 30 Minutes During Wet Runs | | | | | | |
| G1 | 1.42 | 26.11 | 17.30 | 15.40 | 39.66 | 461.95 |
| G2 | 1.74 | 27.92 | 14.50 | 8.73 | 50.61 | 54.79 |
| G3 | 8.33 | 18.42 | 94.28 | 22.48 | 31.04 | 149.57 |

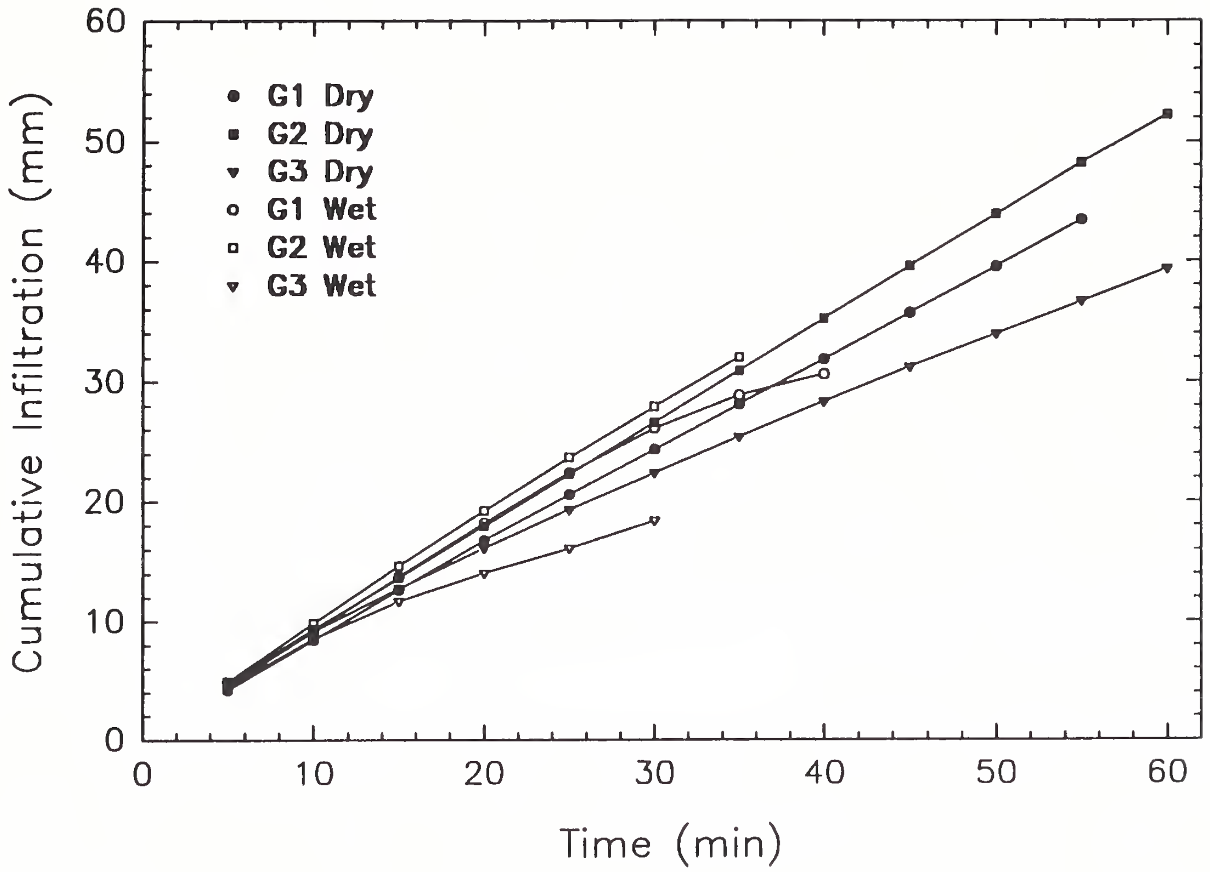


Figure 1. Cumulative infiltration for G1, G2, and G3 sites in Wyoming.

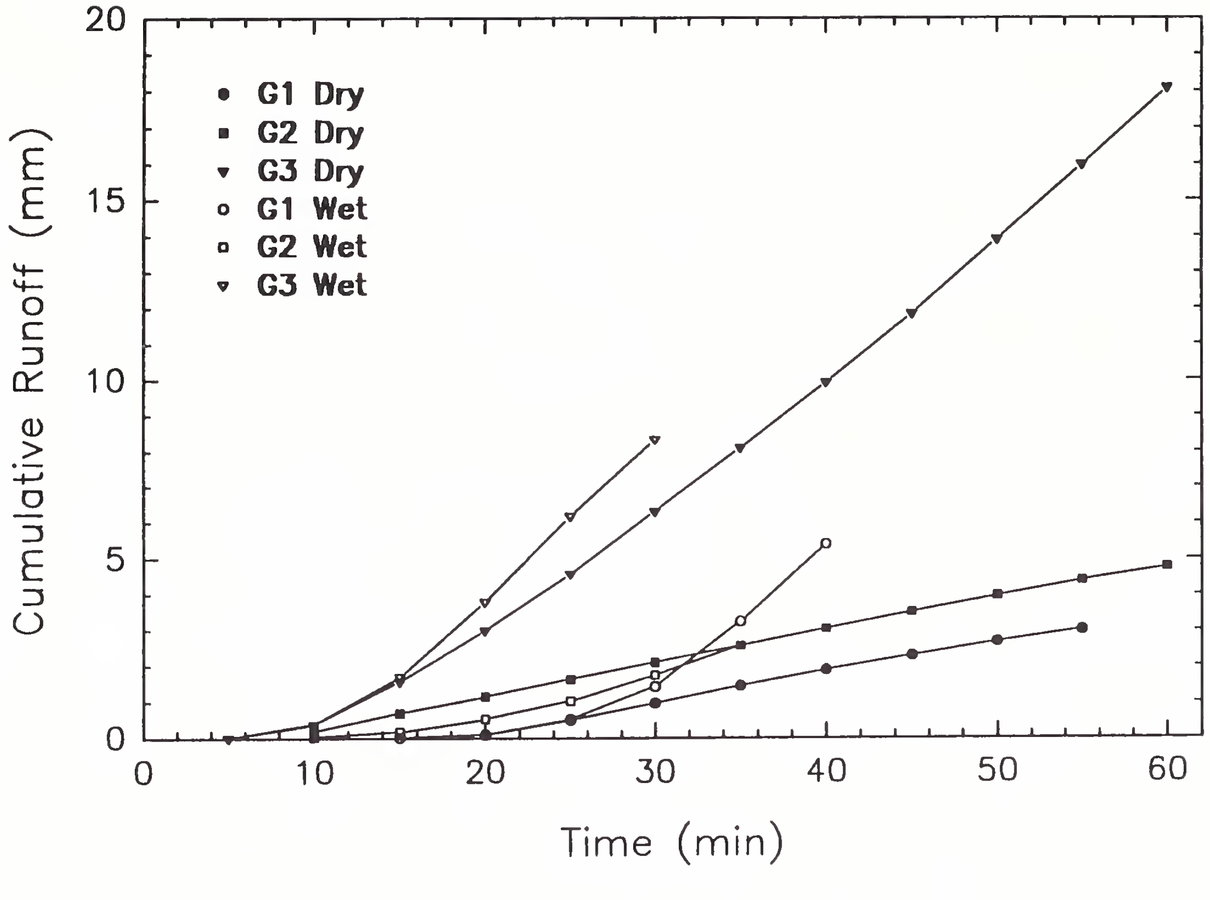


Figure 2. Cumulative runoff for sites G1, G2, and G3 in Wyoming.

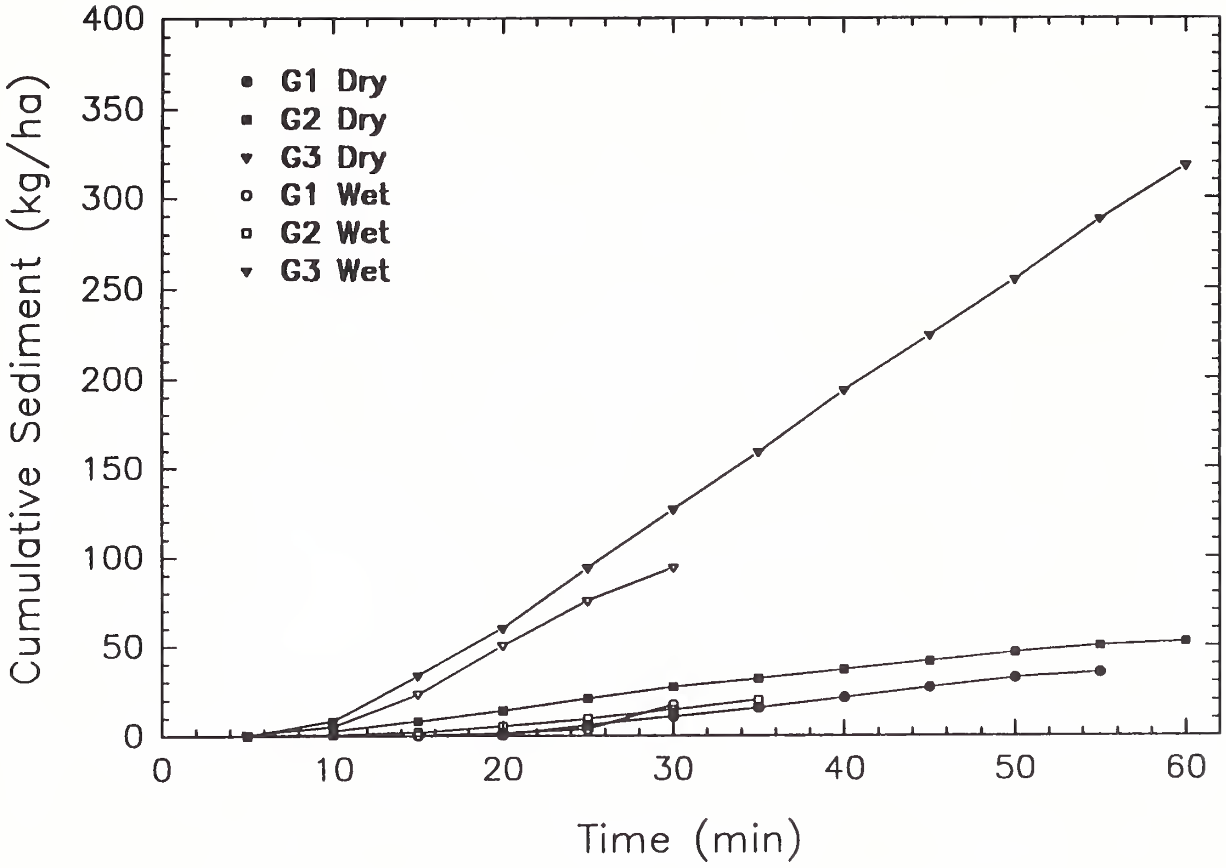


Figure 3. Cumulative sediment yield for sites G1, G2, and G3 in Wyoming.

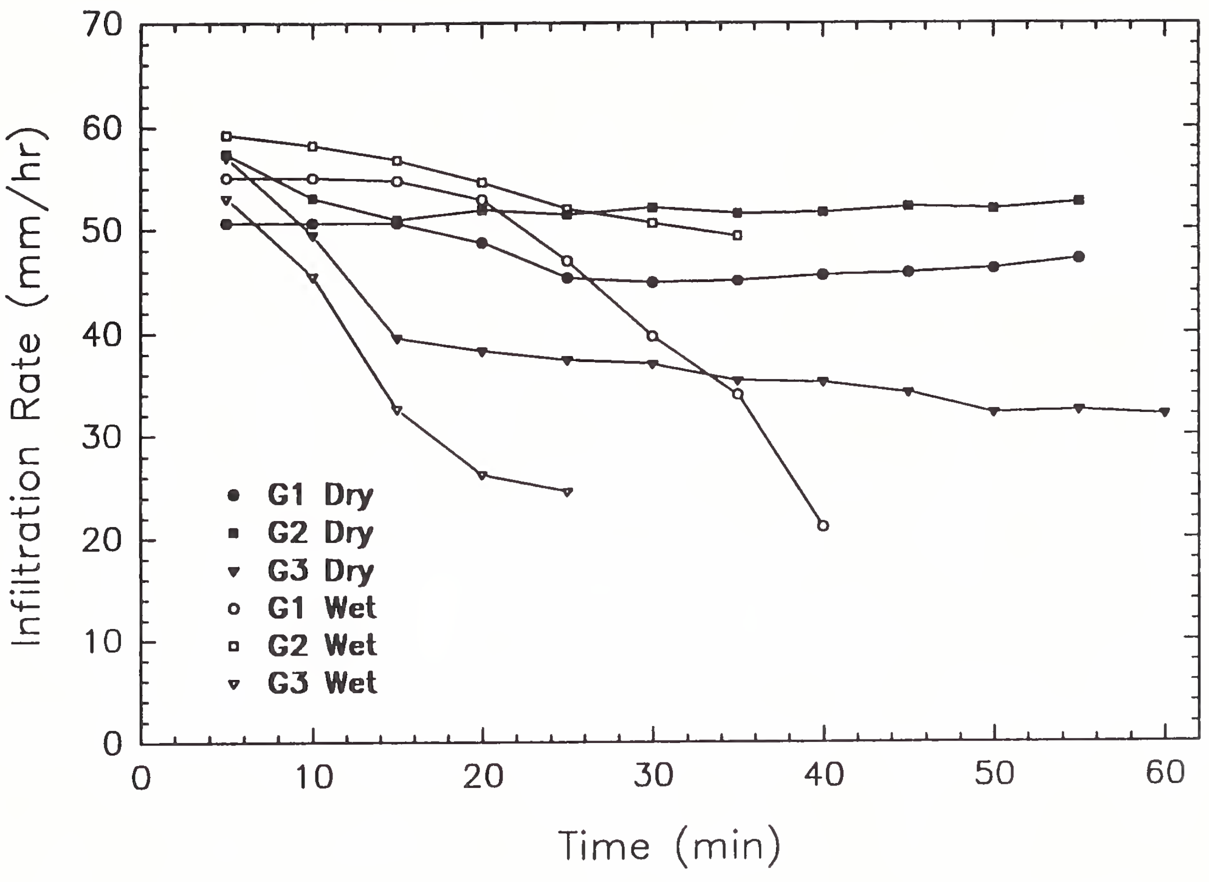


**Figure 4. Instantaneous infiltration rate for sites G1, G2, and G3 in Wyoming.**

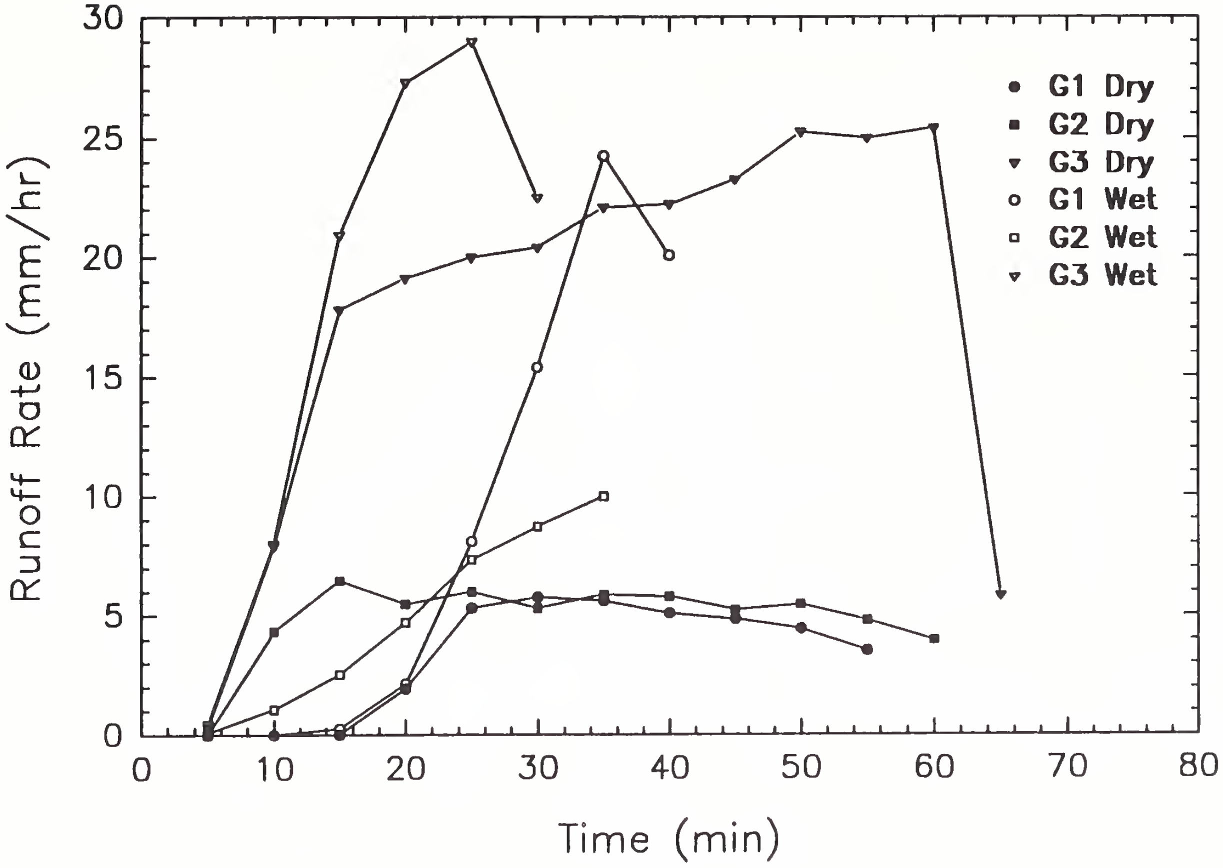


Figure 5. Instantaneous runoff rate for sites G1, G2, and G3 in Wyoming.

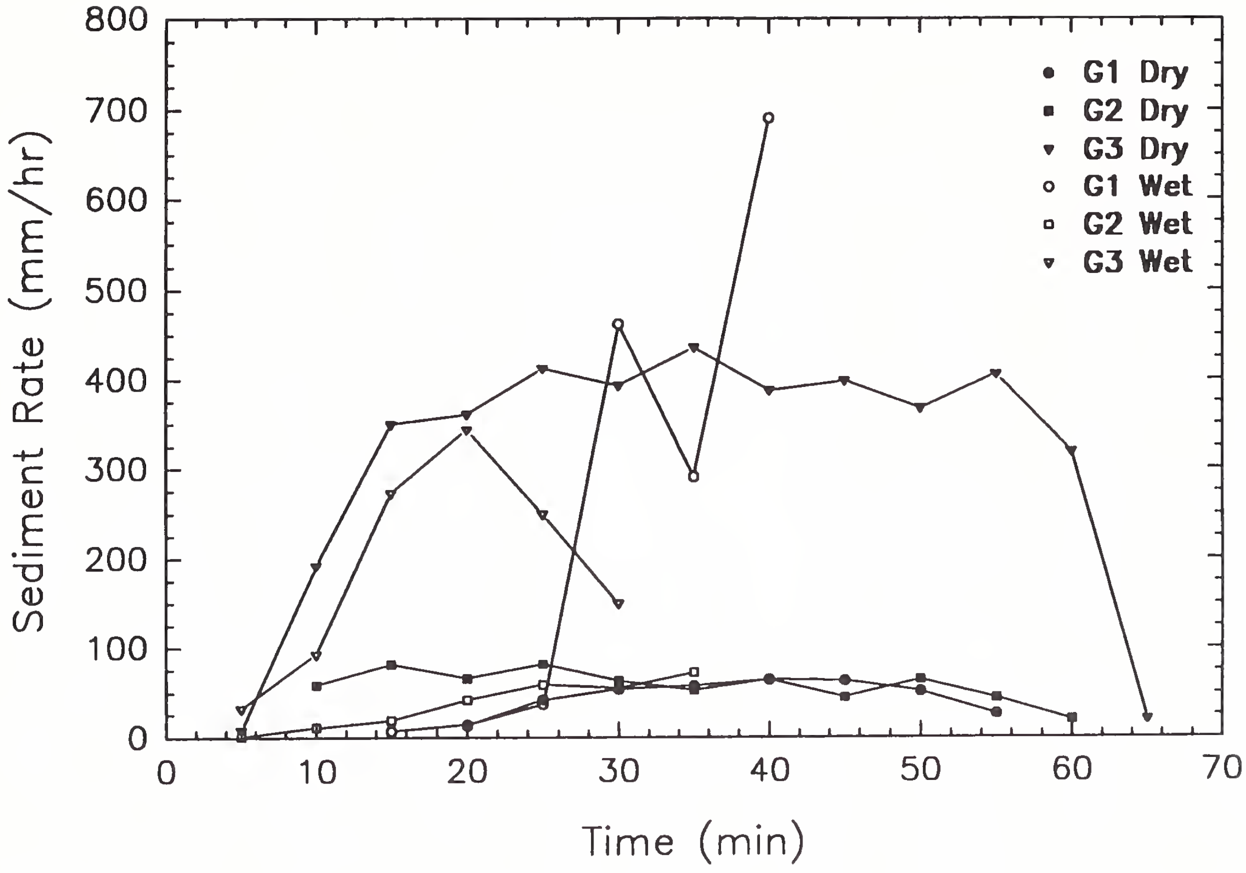


Figure 6. Instantaneous sediment yield rate for sites G1, G2, and G3 in Wyoming.

# APPENDIX II

Publication List

<u>IRWET Publications</u>


1. **Blackburn, W.H., F.B. Pierson, C.L. Hanson, T.L. Thurow and A.L. Hanson.** 1992. The spatial and temporal influence of vegetation on surface soil factors in semiarid rangelands. Trans. of ASAE 35(2):479-486.

2. **Blackburn, W.H. and F.B. Pierson.** 1992. Spatial and temporal soil properties: A key to predicting runoff and erosion from sagebrush-cheatgrass rangelands. Proceedings of symposium: Ecology, management and restoration of intermountain annual rangelands. May 18-21, Boise, Idaho.

3. **Blackburn, W.H., and F.B. Pierson.** 1992. Sources of variation in erosion on rangelands. Proc. Variability in Rangeland Water Erosion Processes. November 4, 1992, Minneapolis, MN.

4. **Blackburn, W.H., F.B. Pierson, C.L. Hanson, T.L. Thurow, and A.L. Hanson.** 1991. Variations in rangeland hydrologic/erosion processes. Presented at the ASAE Summer Meetings, Albuquerque, New Mexico, June 16-23. Paper No. 912019. 14p.

5. **Blackburn, W.H.** 1991. Watershed considerations when planning vegetation management projects. **In:** K.D. Sanders, T.E. Bedell, and B.F. Roche (eds.) Managing herbs and shrubs for multiple uses. The 23rd Annual Pacific NW Range Manage. Shortcourse, Univ. of Idaho, Moscow ID, Feb 12-14. Extended Abstract.

6. **Blackburn, W.H., J.B. Newman and J.C.Wood.** 1991. The conservation reserve program: effects on soil, water and environmental quality, p. 37-45. **In:** L.A. Joyce, J.E. Mitchell, and M.D. Skold (eds.) Proc. The Conservation Reserve-Yesterday Today and Tomorrow. USDA-Forest Service, Rocky Mountain Forest and Range Exp. Sta., Fort Collins CO, Gen. Tech. Rep. RM-203 (Jan. 14). (Invited Paper).

7. **Daughtry, C. S. T., M. A. Weltz, E. M. Perry and W. P. Dulaney.** Gap frequency measurements of leaf area index in soybean and semiarid rangeland canopies. Water Resource Research (In Press).

8. **Daughtry, C. S., M. A. Weltz, E. M. Perry and W. P. Dulaney.** 1991. Direct and indirect estimates of leaf area index. Proc. 20th Amer. Met. Soc. Conf. on Agric. and Forest Met., Spec. Session on Hydromet., Sept. 10-13, Salt Lake City, UT.

9. **Flerchinger, G.N. and F.B. Pierson.** 1991. Modeling plant canopy effects on variability of soil temperature and water. Agric. and For. Meterol. 56:227-246.

10. **Gilley, J.E., D.C. Flanagan, E.R. Kottwitz, and M.A. Weltz.** 1992. Darcy-Weisbach roughness coefficients for overland flow. In Overland Flow, ed. A. J. Parsons, 23-50. University College London Press, London, England.

11. **Hawkins, R.H., V.L. Lopes, R.A. Parker and M.A. Weltz.** 1991. Effects of global climate change on erosion stability in arid environments using WEPP. Proc. US-PRC Bilateral Symposium on Droughts and Arid-Region Hydrology, Oct. 16-20, Tucson, AZ.

12. **Laflan, J., M.A. Weltz, D. Flanagan, and J.J. Stone.** 1992. The WEPP model and its application for predicting erosion on rangelands. Proc. Variability in Rangeland Water Erosion Processes. November 4, 1992, Minneapolis, MN.

13. **Merz, D., K. Spaeth, and P. Shaver.** 1992. Texas small plot rainfall simulation: background and procedures. Texas Range Technical Note. USDA-Soil Conservation Service, Temple, Texas.

14. **Moran, M.S., T.R. Clarke, W.P. Kustas, M.A. Weltz and S.A. Amer.** Evaluation of hydrologic parameters in semiarid rangeland using remotely sensed spectral data. Water Resource Research (In press)

15. **Pierson, F.B., G.N. Flerchinger and J.R. Wight.** 1992. Modeling near-surface soil temperature and water on sagebrush rangeland: A comparison of models. (In Press).

16. **Pierson, F.B., and W.H. Blackburn.** 1992. Seedbed preparation techniques: Impacts on rangeland hydrology and erosion. Proc. Ecology, management and restoration of intermountain annual rangelands. May 18-21, Boise, Idaho.

17. **Pierson, F.B., W.H. Blackburn and S.S. Van Vactor.** 1992. Predicting spatial and temporal variability of soil properties which influence erosion on rangelands. Proc. Variability in Rangeland Water Erosion Processes. November 4, 1992, Minneapolis, MN.

18. **Pierson, F.B., G.N. Flerchinger and J.R. Wight.** 1991. Simulation of the near-surface soil microenvironment - Model complexity. Pres. at ASAE Summer Meeting, June 16-23, Albuquerque NM. Paper No. 91-2008, 17p.

19. **Pierson, F.B. and J.R. Wight.** 1991. Variability of near-surface soil temperature on sagebrush rangeland. J. of Range Manage. 44:491-497.

20. **Ritchie, J.C. and M.A. Weltz.** 1992. Using an airborne laser to measure vegetation properties. American Society of Photogrammetric and Remote Sensing and American Congress on Surveying and Mapping. Washington, DC. 4:395-405.

21. **Sellars, D.V., K.E. Spaeth. and M. Peterson.** 1992. A guidance document for restoring and enhancing rangeland/pastureland watersheds. Society for Range Management Publ. (In Press).

22. **Seyfried, M.S.** 1991. Infiltration patterns in simulated rainfall on a semiarid rangeland. Soil Sci. Soc. of Amer. J., 55(6):1726-1734.

23. **Simanton, J.R., M.A. Weltz, L.J. Lane and H.D. Larsen.** 1991. Rangeland experiments to parameterize the Water Erosion Prediction Project model: Vegetation canopy cover effect. J. Range Manage. 44:276-282.

24. **Spaeth, K.E., M.A. Weltz, and H.D. Fox. 1992.** Spatial pattern analysis of sagebrush vegetation and potential influences on hydrology and erosion. Proc. Variability in Rangeland Water Erosion Processes. Nov. 1-6, Minneapolis, MN.

25. **Spaeth, K.E., and R.E. Sosebee.** 1991. Hydrologic assessments of plant community types and successional stages on a discrete range site on the southern High Plains. p. 52-67. In: Proceedings from the Regional Lake Conference, Des Moines, Iowa, June 1991. Iowa State University, University Extension.

26. **Spaeth, K.E., and H.D. Fox.** 1992. Range Hydrology: National Range Handbook. In review. USDA-Soil Conservation Service, Washington, D.C.

27. **Tiscareno-Lopez, M., V.L. Lopes, J.J. Stone, L.J. Lane.** Sensitivity analysis of the WEPP watershed model for rangeland applications. I: Hillslope processes. Trans. Amer. Soc. Agric. Eng. (In press)

28. **Tiscareno-Lopez, M., V.L. Lpoes, J.J. Stone, L.J. Lane.** Sensitivity analysis of the WEPP watershed model for rangeland applications. II: Channel processes. Trans. Amer. Soc. Agric. Eng. (In press)

29. **Weltz, M.A., A.B. Arslan and L.J. Lane.** 1992. Hydraulic roughness coefficients for native rangelands. ASCE J. Irrigation and Drainage. 118:776-790.

30. **Weltz, M.A. and W.H. Blackburn.** Modeling water balance with the ERHYM model on South Texas rangelands. Water Resource Bull. (Accepted 2/92)

31. **Weltz, M.A., W.H. Blackburn and J.R. Simanton.** Leaf area ratios for selected rangeland plant species. Great Basin Naturalist. (In Press).

32. **Weltz, D.C. Goodrich and L.B. Bach.** Soil moisture sensors for continuous monitoring. Water Resources Research (In Press).

33. **Weltz, M.A., J.C. Ritchie and H.D. Fox.** Comparison of laser and field measurements of vegetation height and canopy cover. Water Resource Research (In Press) .

34. **Wilcox, B.P., W.H. Blackburn and A. Agdi.** 1991. Erosion prediction from sagebrush rangeland using WEPP. 44th annual meeting, Soc. for Range Manage., Washington D.C., January 12-17, Abstract No. 32.

35. **Wilcox, B.P., M. Sbaa, W.H. Blackburn and J.H. Milligan.** 1991. Runoff prediction from sagebrush rangelands using Water Erosion Prediction Project (WEPP) technology. J. of Range Manage. (In press)

36. **Wilcox, B.P., M.S. Seyfried, K.R. Cooley and C.L. Hanson.** 1991. Runoff characteristics of sagebrush rangelands: Modeling implications. J. of Soil and Water Conserv. 46:153-158.

37. **Wilcox, B.P., M.S. Seyfried and T. Matison.** 1991. Searching for chaotic dynamics in snowmelt runoff. Water Resources Res. 27:1005-1010.

## IRWET Presentations:

1. **Blackburn, W.H. and F.B. Pierson.** 1992. Spatial and temporal soil properties: A key to predicting runoff and erosion from sagebrush-cheatgrass rangelands. Symposium: Ecology, management and restoration of intermountain annual rangelands. May 18-21, Boise, Idaho.

2. **Blackburn, W.H., and F.B. Pierson.** 1992. Sources of variation in erosion on rangelands. Symposium on Variability in Rangeland Water Erosion Processes. Nov. 4, 1992, Minneapolis, MN.

3. **Fox, H.D., M.A. Weltz, K.E. Spaeth, L. Ledbetter.** Influence of spatial and temporal distribution of ground cover and soil erosion and surface runoff. Presented at Society for Range Management Annual meeting Feb. 13-19, Albuquerque, NM. 1993.

4. **Laflan, J., M.A. Weltz, D. Flanagan, and J.J. Stone.** 1992. The WEPP model and its application for predicting erosion on rangelands. Presented at Soil Science Soc. America Annual Meeting Nov. 1-6, Minneapolis, MN.

5. **Pierson, F.B., and W.H. Blackburn.** 1992. Seedbed preparation techniques: Impacts on rangeland hydrology and erosion. Symposium: Ecology, management and restoration of intermountain annual rangelands. May 18-21, Boise, Idaho.

6. **Pierson, F.B., W.H. Blackburn and S.S. Van Vactor.** 1992. Predicting spatial and temporal variability of soil properties which influence erosion on rangelands. Symposium on Variability in Rangeland Water Erosion Processes. November 4, 1992, Minneapolis, MN.

7. **Pierson, F.B. and J.R. Wight.** 1991. Spatial and temporal variability of soil water and temperature on sagebrush rangelands. **In:** Abstracts-Rangeland Resources Influencing Change in a Global Setting, Soc. of Range Manage., Jan 12-17, Washington, DC, Abstract #15, p. 30.

8. **Seyfried, M.S.** 1991. Estimation of the effect of soil-water content on frozen soil permeability. Agronomy Abstracts, p. 231.

9. **Spaeth, K.E., D. Schmidt, W. Vander Vorste, and R. Voss.** 1992. Hydrologic assessments within the Bad River Watershed of South Dakota. Society for Range Management 45th Annual Meeting, February 9-14, 1992, Spokane, Washington.

10. **Spaeth, K.E., M.A. Weltz, and H.D. Fox. 1992.** Spatial pattern analysis of sagebrush vegetation and potential influences on hydrology and erosion. Symposium: Variability in Rangeland Water Erosion Processes. Soil Science Soc. Amer., 84th Annual Meeting Program, Minneapolis, MN., Nov. 1-6, 1992.

11. **Tiscareno-Lopez, M., V.L. Lopes, J.J. Stone. and L.J. Lane.** 1992. Sensitivity analysis of the WEPP watershed model for rangeland conditions. Paper 92-2018. American Society of Agricultural Engineers Annual Meeting June, 21-24, Charlotte, NC.

## Historical Publications related to IRWET and the WEPP model from the ARS Boise and Tucson Units:

1. **Alberts, E.E., J.M. Laflen, W.J. Rawls, J.R. Simanton, and M.A. Nearing.** 1989. Chapt. 6 Soil Component. USDA-Water Erosion Prediction Project: Hillslope Profile Model Documentation, eds. L.J. Lane and M.A. Nearing, NSERL Report No. 2, USDA-ARS National Soil Erosion Res. Lab., Indiana. 6.1-6.15.

2. **Alberts, E. E., M. A. Weltz and F. Ghidy.** 1989. Plant Growth Component. In: L. J. Lane and M. A. Nearing (ed), WEPP Profile Model Documentation. NSERL Report No. 2, USDA-ARS, W. Lafayette, IN. 8.1-8.50.

3. **Blackburn, W.H. and M.K. Wood.** 1990. Influence of soil frost on infiltration of shrub coppice dune and dune interspace soils in southeastern Nevada. Great Basin Naturalist. 50:41-46.

4. **Blackburn, W.H., F.B. Pierson and M.S. Seyfried.** 1990. Spatial and temporal influence of soil frost on infiltration and erosion of sagebrush rangelands. Water Resources Bull. 26(6):991-997.

5. **Drungil, C.E.C., R.H. McCuen, and J.R. Simanton.** 1990. Application of low altitude photogrammetry to the determination of rangeland hydraulic parameters. Trans. of ASAE, 33:1919-1924.

6. **Gilley, J. E., S. C. Finker, M. A. Nearing, L. J. Lane and M. A. Weltz.** 1990. Hydraulics of overland flow. In: D. C. Flanagan (ed), WEPP Second Edition. NSERL Report No. 4. USDA-ARS, W. Lafayette, IN. , 9.1-9.9.

7. **Gilley, J.E., E.R. Kottwitz, and J.R. Simanton.** 1990. Hydraulic characteristics of rills. Trans. of ASAE, 33:1900-1906.

8. **Johnson, C.W. and N.D. Gordon.** 1988. Runoff and erosion from rainfall simulator plots on sagebrush rangeland. Trans. of ASAE. 31:421-427.

9. **Johnson C.W. and W.H. Blackburn.** 1989. Factors contributing to sagebrush rangeland soil loss. Trans. of ASAE. 32:155-160.

10. **Lane, L. J., A.D. Nicks, J.M. Laflen, M.A. Weltz, W.J. Rawls and D.I. Page.** 1989. The Water Erosion Prediction Project: Model overview. Proceedings of National Water Conference IR and WR Divs/ASCE, Newark, Dl, July 17-20. pp. 487-494.

11. **Nearing, M. A., M. A. Weltz, S. C. Finkner, J. J. Stone and L. T. West.** 1989. Parameter Identification from Plot Data, 11.1-11.20. In: L. J. Lane and M. A. Nearing (ed), WEPP Profile Model Documentation. NSERL Report No. 2, USDA-ARS, W. Lafayette, IN.

12. **Pierson, F.B., Jr., W.H. Blackburn, M.S. Seyfried and J.C. Wood.** 1990. Soil frost effects on spatial and temporal variability of infiltration and interrill erosion within a sagebrush-grassland plant community. Abstract No. 262, **In:** Abstracts of the 43rd Annual Meeting, Soc. for Range Manage., Reno NV, Feb. 11-16.

13. **Rawls, W.J., D.L. Brakensiek, J.R. Simanton, and K.D. Kohl.** 1990. Development of a crust factor for a Green Ampt model. Trans. of ASAE, 33:1224-1228.

14. **Savabi, M.R., W.J. Rawls and J.R. Simanton.** 1990. Rangeland evaluation of WEPP hydrology. In: Watershed Planning and Analysis in Action, Symposium Proceedings of IR Conference, Watershed Mgt/IR Div. ASCE, Durango, CO July 9-11, pp. 77-87.

15. **Simanton, J. R., G. D. Wingate and M. A. Weltz.** 1990. Runoff and sediment from a burned sagebrush community. In: J. S. Krammes (ed), Effects of Fire Management of Southwestern Natural Resources. USDA Forest service Report RM-191.

16. **Simanton, J.R., L.T. West, M. A. Weltz and G. D. Wingate.** 1987. Rangeland experiments for water erosion prediction project. Paper No. 87-2545, American Society of Agricultural Engineers, St. Joseph, MI.

17. **Spaeth, K.E.** 1990. Hydrologic and ecological assessments of a discrete range site on the southern High Plains. Ph.D. Dissertation, Texas Tech. Univ., Lubbock, TX.

18. **Weltz, M. A. and A. B. Arslan.** 1990. Water Erosion Prediction Project (WEPP): Estimating plant components that are used to simulate soil erosion on rangelands. In: G. Singh (ed), International Symposium on Water Erosion, Sedimentation and Resource Conservation. October 9-13, Dehradun, India, pp. 71-83.

19. **Weltz, M. A., M. K. Wood and E. E. Parker.** 1989. Flash grazing and trampling: effects on infiltration rates and sediment yield on a selected New Mexico range site. J. Arid Environments, 16:95-100.

20. **Wilcox, B.P, C.L. Hanson, J.R. Wight and W.H. Blackburn.** 1989. Sagebrush rangeland hydrology and evaluation of the SPUR model. Water Resources Bulletin. 25:653-666.

21. **Wilcox, B.P., K.R. Cooley and C.L. Hanson.** 1989. Predicting snowmelt runoff on sagebrush rangeland using a calibrated SPUR model. Trans. of ASAE. 32:1351-1357.

22. **Wilcox, B.P., W.J. Rawls, D.L. Brakensiek and J.R. Wight.** 1990. Predicting runoff from rangeland catchments: A comparison of two models. Water Resources Research. 26:2401-2410.